Biological & Medical Series

September 1921 | Chemical Series | Vol. VI, No. 2

Memoirs of the Department of Agriculture in India

STORAGE

INVESTIGATIONS ON INDIAN OPIUM, NO. 2

THE EFFECT OF ENVIRONMENTAL FACTORS ON THE ALKALOIDAL CONTENT AND YIELD OF LATEX FROM THE OPIUM POPPY (*PAPAVER SOMNIFERUM*) AND THE BEARING OF THE WORK ON THE FUNCTIONS OF ALKALOIDS IN PLANT LIFE

BY

HAROLD E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.E.A.C., Etc

Agricultural Chemist to the Government of Bengal, on Special Duty

Thesis approved for the Degree of Doctor of Science in the University of London)

LIBRARY MAR 15 1953

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Price, Rs. 2 or 2s. 9d

EDITED BY

The Council of the Pusa Agricultural Research Institute which is not, as a body, responsible for the opinions expressed in the Memoir.

September 1921 CHEMICAL SERIES Vol. VI, No. 2

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

INVESTIGATIONS ON INDIAN OPIUM, NO. 2

THE EFFECT OF ENVIRONMENTAL FACTORS ON THE ALKALOIDAL CONTENT AND YIELD OF LATEX FROM THE OPIUM POPPY (*PAPAVER SOMNIFERUM*) AND THE BEARING OF THE WORK ON THE FUNCTIONS OF ALKALOIDS IN PLANT LIFE

BY

HAROLD E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.F.A.C., ETC

Agricultural Chemist to the Government of Bengal, on Special Duty at Cawnpore

(Thesis approved for the Degree of Doctor of Science in the University of London)

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Agents for the Sale of Government Publications

IN THE UNITED KINGDOM

Constable & Co., 10, Orange Street, Leicester Square, London, W.C.

Kegan Paul, Trench Trübner & Co., 68-74, Carter Lane, E.C., and 39, New Oxford Street, London, W.C.

Bernard Quaritch, 11, Grafton Street, New Bond Street, London, W.

P. S. King & Sons, 2 and 4, Great Smith Street, Westminster, London, S.W.

H. S. King & Co., 65, Cornhill, E.C., and Pall Mall, London, W.

Grindlay & Co., 54, Parliament Street, London, S.W.

T. Fisher Unwin, Ltd., 1, Adelphi Terrace, London, W.C.

W. Thacker & Co., 2, Creed Lane, London, E.C.

Luzac & Co., 46, Great Russell Street, London, W.C.

Wheldon & Wesley, Ltd., 28, Essex Street, London, W.C.

B. H. Blackwell, 50 and 51, Broad Street, Oxford.

Deighton, Bell & Co., Ltd., Cambridge.

Oliver & Boyd, Tweedale Court, Edinburgh.

E. Ponsonby, Ltd., 116, Grafton Street, Dublin.

ON THE CONTINENT

Ernest Leroux, 28, Rue Bonaparte, Paris.

Martinus Nijhoff, The Hague, Holland.

IN INDIA AND CEYLON

Thacker, Spink & Co., Calcutta and Simla.

W. Newman & Co., Calcutta.

R. Cambray & Co., Calcutta.

S. K. Lahiri & Co., Calcutta.

B. Banerjee & Co., Calcutta.

The Indian School Supply Depôt, 309, Bow Bazar Street, Calcutta, and 226, Nawabpur, Dacca.

Butterworth & Co. (India), Limited, Calcutta.

The Weldon Library, 18-5, Chowringhee Road, Calcutta.

Rai M. C. Sircar Bahadur and Sons, 75-1-1, Harrison Road, Calcutta.

Standard Literature Co., Ltd., Calcutta.

Lal Chand and Sons, Calcutta.

Association Press, Calcutta.

Higginbothams, Ltd., Madras.

V. Kalyanarama Iyer & Co., Madras.

G. A. Natesan & Co., Madras.

S. Murthy & Co., Madras.

Thompson & Co., Madras.

Temple & Co., Madras.

P. R. Rama Iyer & Co., Madras.

Vas & Co., Madras.

E. M. Gopalkrishna Kone, Madras.

Thacker & Co., Ltd., Bombay.

D. B. Taraporevala, Son & Co., Bombay.

Radhabai Atmaram Sagoon, Bombay.

Sunder Pandurang, Bombay.

Gopal Narayan & Co., Bombay.

Ramchandra Govind & Son, Kalbadevi, Bombay.

Proprietor, New Kitabkhana, Poona.

The Standard Bookstall, Karachi.

Mangaldas Harkisandas, Surat.

Karsandas Narandas & Sons, Surat.

A. H. Wheeler & Co., Allahabad, Calcutta and Bombay.

N. B. Mathur, Superintendent, Nazir Kanun-i-Hind Press, Allahabad.

Munshi Seeta Ram, Managing Proprietor, Indian Army Book Depôt, Juhi, Cawnpore.

Rama Krishana and Sons, Lahore.

Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore.

Superintendent, American Baptist Mission Press, Rangoon.

Manager, the "Hitavada," Nagpur.

S. C. Talukdar, Proprietor, Students and Company, Cooch Behar.

A. M. & J. Ferguson, Colombo, Ceylon.

CONTENTS

	Page
Introduction	61
The influence of the number of capsules on the plant	62
The influence of the age of the capsules	75
The influence of manures	89
The influence of starvation	120
The influence of climate, season and weather conditions	121
The function of alkaloids in plants	144

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

http://www.archive.org/details/n2memoirschemica06impeuoft

INVESTIGATIONS ON INDIAN OPIUM, No. 2.

THE EFFECT OF ENVIRONMENTAL FACTORS ON THE ALKALOIDAL CONTENT AND YIELD OF LATEX FROM THE OPIUM POPPY (*PAPAVER SOMNIFERUM*) AND THE BEARING OF THE WORK ON THE FUNCTIONS OF ALKALOIDS IN PLANT LIFE.

BY

HAROLD E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.E.A.C., Etc.,

Agricultural Chemist to the Government of Bengal, on Special Duty at Cawnpore.

[Received for publication on the 7th July, 1920.]

INTRODUCTION.

The writer in collaboration with others has described the manner in which alkaloid content and yield of poppy latex are influenced by factors of a non-environmental nature. The effects there considered were practically all connected with the methods of lancing and collection adopted. In this memoir it is proposed to give an account of the effect of certain environmental factors on the alkaloidal content and yield of latex. In this connection the effects of manures, climate, season and of weather conditions are considered. The stage of development of the capsule yielding latex is practically an environmental factor, and is included in this account. The number of capsules on a plant depends to a large extent on environment, and, as will be shown below, the capsule first produced by the plant produces latex of a very different composition from that of the latex from the capsules subsequently appearing. When, therefore, one is dealing with effects due to weather conditions, manures or age of capsules, it is important to confine one's attention to the latex produced by the oldest capsule only of each plant. Because of this, it is

proposed to deal first with the yield and composition of the latex of the oldest and of the younger capsules of each plant. In order to follow the acc unt of the work, the description of the method of lancing the capsules for opium should be read.[1]

THE INFLUENCE OF THE NUMBER OF CAPSULES ON THE PLANT.

The writer has observed as many as 40 capsules in various stages of development on a plant of the opium poppy. Usually, however, the plants have one or two, or, perhaps, three capsules. The oldest is at the end of the main stem. The subsequent capsules are borne each at the end of a branch arising from an axil of a leaf on the main stem, and the younger the capsule the further down the main stem does its branch originate. Moreover, the youngest lateral capsule overtops all the rest, so that the original, or terminal, capsule can generally easily be recognized from the fact that it is overtopped by all the others. It seemed of interest to determine if there were any differences to be observed between the yield and composition of the opium obtained from the oldest capsules on a plant, and from those subsequently appearing. The following experiment was carried out at Almorah in the Himalayas. A number of plants, with at least 5 capsules each, were taken in such a stage that their terminal capsules were ready for lancing. These latter were lanced. In the opium produced estimations were made of the total dry matter and of the percentage of morphine.

Three days later, the next oldest capsules on these plants, *i.e.*, the first lateral capsules, were lanced. Only 146 were ready for lancing. These will be referred to as the first lateral capsules. Three days later the next oldest capsules on the plants were lanced : 334 were taken. These are designated the second lateral capsules. Three days later the third lateral capsules, 120 in number, were lanced. The varying numbers of the terminal, 1st, 2nd and 3rd lateral capsules lanced were due of course to the fact that, though the terminal capsules in all the plants were ready on the same day, because they were chosen for this reason, the 1st lateral capsules of all the plants were not ready on one day and so on. In each case, as many subsequent lancings were applied as the capsules would bear. The results are set out in the following table :—

[1] Annett, Sen and Singh. *Mem. Dept. Agri. India (Chem. Series)*, vol. VI, no. 1 (pt. II).

No. of lancing	Terminal capsules					Lateral capsules														
						1st lateral capsules					2nd lateral capsules					3rd lateral capsules				
	Date of lancing	No. of capsules lanced	Weight of dried opium (grm.)	Weight of dried opium per 1,000 capsules (grm.)	Per cent. of morphine in dry matter of opium	Date of lancing	No. of capsules lanced	Weight of dried opium (grm.)	Weight of dried opium per 1,000 capsules (grm.)	Per cent. of morphine in dry matter of opium	Date of lancing	No. of capsules lanced	Weight of dried opium (grm.)	Weight of dried opium per 1,000 capsules (grm.)	Per cent. of morphine in dry matter of opium	Date of lancing	No. of capsules lanced	Weight of dried opium (grm.)	Weight of dried opium per 1,000 capsules (grm.)	Per cent. of morphine in dry matter of opium
1st	20–4–17	491	16·25	33·10	11·9	23–4	146	2·70	18·50	7·30	26–4	334	6·45	19·31	9·46	29–4	120	0·50	4·25	—
2nd	23–4–17	491	18·80	38·29	9·57	26–4	146	1·95	13·36	6·04	29–4	334	2·95	8·83	4·90	2–5	120	1·60	13·33	—
3rd	26–4–17	491	9·25	18·44	5·81	29–4	146	1·35	9·25	—	2–5	334	5·80	17·38	3·02	10–5	57	0·75	13·16	—
4th	29–4–17	491	5·70	11·61	3·64	2–5	146	1·65	11·30	—	10–5	196	11·90	9·70	1·78	12–5	35	0·25	7·14	—
5th	2–5–17	491	12·45	25·35	2·16	10–5	71	1·00	14·06	—	12–5	123	0·55	4·47	—	—	—	—	—	—
6th	10–5–17	251	3·15	12·55	1·59	12–5	40	0·30	7·5	—	—	—	—	—	—	—	—	—	—	—
7th	12–5–17	119	0·80	6·72	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

The results are very definite. Dealing, firstly, with the yield of dry opium per 1,000 capsules, it will be seen that the terminal capsules are much the heaviest yielders. They gave nearly twice as much opium at the first lancing as the lateral capules, and 3 to 4 times as much at the second lancing.

Turning to the morphine content in the dry opium, one finds that at each lancing it is far greater in the case of the terminal than in the lateral capsules. In the season 1917-18 further investigations on these lines were carried out. A number of plants with three capsules, of which the terminal was ready for lancing, were selected on the same day, *viz.*, 2nd March, 1918. Each was marked with a piece of red cloth, so that they could easily be found.

The terminal capsules were lanced on that day, and counted, and the opium collected next morning. These capsules received further lancings on the 5th, 9th, and 12th March. On the 5th March, any lateral capsules ready for lancing, namely, 1,053, were lanced and the opium collected next day. These subsequently received a second, third, and fourth lancing on the 9th, 12th and 15th March. On the 9th March, a fresh lot of lateral capsules were ready for lancing. These received a second and a third lancing on the 12th and 15th March. On the 12th March, still more lateral capsules were ready for lancing. These received a second lancing on the 15th March. The number of heads of each lancing was counted and the yield of dry opium and its morphine content were estimated. The results are summarized in the table.

Sample	No. of lancing	Date of lancing	No. of capsules yielding latex	Grm. opium (dried in steam oven)	Grm. opium per 1,000 capsules	Percentage of morphine in dry matter of opium
Terminal capsules	1st	2–3–18	1,620	129·80	79·7	14·0
	2nd	5–3–18		43·76	27·0	8·4
	3rd	9–3–18		13·34	8·2	5·3
	4th	12–3–18		5·70	3·5	3·3
Lateral capsules	1st	5–3–18	1,053	36·39	34·6	12·2
	2nd	9–3–18		8·40	8·0	7·1
	3rd	12–3–18		2·24	2·2	4·9
	4th	15–3–18		0·30	0·3	..
Lateral capsules, 2nd crop	1st	9–3–18	1,563	21·52	13·7	10·1
	2nd	12–3–18		10·10	6·5	6·1
	3rd	15–3–18		1·10	0·7	..
Lateral capsules, 3rd crop	1st	12–3–18	193	2·77	14·3	3·0

In the season 1917-18, a further experiment on the same lines was carried out in the Kumaun Hills at Douglas Dale near Naini Tal. A number of plants having more than one capsule were taken. In order to have duplicate results they were divided into two roughly equal groups, the actual number of plants in each group being 407 and 376.

The terminal capsule and also the oldest lateral capsule on each plant were lanced. The table sets out all the results.

	Number of lancing									
	First		Second		Third		Fourth		Fifth	
	Grm. dry opium per 1,000 capsules	Per cent. morphine in dry opium	Grm dry opium per 1,000 capsules	Per cent. morphine in dry opium	Grm. dry opium per 1,000 capsules	Per cent. morphine in dry opium	Grm. dry opium per 1,000 capsules	Per cent. morphine in dry opium	Grm. dry opium per 1,000 capsules	Per cent. morphine in dry opium
407 terminal capsules of 407 plants	31·4	15·7	39·8	12·8	33·1	7·5	17·9	9·4	19·5	2·8
407 lateral capsules of same plants	12·8	8·2	18·1	5·9	15·3	1·6	10·5	1·3	9·1	0·0
376 terminal capsules of 376 plants	20·1	16·7	27·4	13·4	35·6	8·1	38·6	5·9	17·5	0·0
376 lateral capsules of same plants	9·2	7·7	19·7	6·8	19·0	3·2	20·0	2·8	8·5	0·0

The table brings out very clearly the low morphine content of the opium from lateral capsules. Moreover, the morphine content of opium from the subsequent lancings falls off much more rapidly than it does in the cases of terminal capsules. Further, the yield of opium from the lateral capsules is far smaller than from the terminal capsules.

It appeared to be of interest to determine whether lateral capsules would give opium of higher morphine content if the terminal capsules on the same plants were left unlanced. Accordingly, about 500 plants with two or more capsules, but whose terminal capsules were all ripe for lancing, were selected and labelled with red cloth labels. About 500 plants on the same plot of the same pure race having two or more capsules, but on which a lateral capsule was ready for lancing, were also selected on the same day and distinguished with paper labels.

The terminal capsules of the red labelled plants and one mature lateral capsule on each of the paper-labelled plants were then lanced on that same day. Three simultaneous cuts per head were made at each lancing instead of the usual one. Unfortunately, the result of this was that only two lancings were obtained and the yield of the second lancing was too small for analysis in the case of the lateral capsules.

The results are set out below :—

Groups	No. of lancing	Date of lancing	Grm. opium (dried in steam oven)	No. of capsules yielding latex	Dry opium per 1,000 capsules grm.	Percentage of morphine in dry opium
RED LABELS						
Terminal capsules lanced	1st	8–3–18	44·52	456	97·2	15·0
	2nd	11–3–18	7·08	224	15·5	7·1
PAPER LABELS						
Lateral capsules only lanced	1st	8–3–18	30·77	462	55·8	12·4
	2nd	11–3–18	1·63	64	3·6	..

These results indicate that even when the terminal capsules are unlanced, the lateral capsules yield much less opium, and also the opium contains less morphine. The result is extremely interesting, inasmuch as it would indicate that the latex most concentrated in morphine cannot be attracted away from the terminal capsules.

Arrangements were therefore made to investigate this point more thoroughly in the season 1918-19. The writer is indebted to Dr. J. N. Sen for carrying on these experiments to a successful conclusion during the former's sudden illness. A field measuring 0·56 acre was selected, on which a pure race of poppy was growing. It was divided into 5 plots, A, B, C, D, and E. For the purpose of the experiment, plants were selected which had more than one capsule each. The following procedure was then adopted in each of the plots.

Plot A. Only the terminal capsule on each plant was lanced. The lateral capsules were left on the plants unlanced.

Plot B. Only lateral capsules were lanced and the terminal capsules were left on the plants unlanced.

Plot C. The terminal capsules were lanced, all lateral capsules havin been removed from the plants just previously.

Plot D. Lateral capsules only were lanced, the terminal capsules on the same plants having been removed just previous to lancing.

Plot E. Both terminal and lateral capsules on the same plants were lanced but the produce of the former was kept separately from that of the latter. Naturally, in this case, the lateral capsules were not ready for lancing till some days after the lancing of the terminal capsules.

In each of the above cases five successive lancings of the capsules were made, and at each lancing only one incision with a four-bladed knife was made. The results are tabulated below.

Description of experiment	No. of lancing	No. of heads lanced	Yield of opium (dry matter) grm.	Yield per 1,000 capsules grm.	Percentage of morphine in dry opium
A					
Terminal capsules lanced, unlanced laterals left on plant	1st	807	18·15	22·48	14·5
	2nd		41·35	51·25	11·6
	3rd		45·52	57·65	7·8
	4th		14·51	18·00	4·0
	5th		2·90	3·59	2·7
TOTAL			122·43	152·97	
B					
Lateral capsules lanced, unlanced terminals left on plant	1st	832	40·24	48·36	11·8
	2nd		43·20	51·92	9·2
	3rd		22·42	25·74	6·1
	4th		2·14	2·57	4·4
	5th		0·40	0·48	..
TOTAL			108·40	129·07	
C					
Terminal capsules, lanced, unlanced laterals previously removed	1st	1,942	100·68	51·85	14·4
	2nd		96·72	49·80	10·7
	3rd		58·87	30·31	7·3
	4th		26·25	13·51	5·4
	5th		0·80	0·41	..
TOTAL			283·32	145·88	
D					
Lateral capsules lanced, unlanced terminals previously removed	1st	1,970	110·16	55·91	10·9
	2nd		112·73	57·21	7·2
	3rd		34·09	17·26	5·0
	4th		12·70	6·40	2·6
	5th		0·45	0·23	..
TOTAL			270·13	137·01	

Description of experiment	No. of lancing	No. of heads lanced	Yield of opium (dry matter) grm.	Yield per 1,000 capsules grm.	Percentage of morphine in dry opium
E					
Both terminal and lateral capsules on same plants lanced	Terminal 1st		40·28	65·71	13·6
	2nd		39·15	63·86	9·0
	3rd	613	13·64	22·25	4·4
	4th		0·91	1·60	..
	5th		0·19	0·40	..
TOTAL			94·17	153·82	..
	Lateral 1st		22·82	31·14	8·8
	2nd		25·50	34·80	5·2
	3rd	733	2·43	3·35	..
	4th		0·49	0·68	..
	5th		0·31	0·42	..
TOTAL			51·55	70·31	

As regards morphine content of the opium produced, the foregoing table shows that the lateral capsules produce poorer opium than the terminal capsules do, whether the terminal capsules on the same plants are removed or not. When, as in plot E, the terminal capsules have been lanced, the opium of the lateral capsules, lanced later, in the same plants is of particularly low morphine content. Turning to the yield of opium it appears that the removal of lateral capsules, previous to lancing the terminal capsules, does not result in any increased yield of latex from the terminal capsules. Neither is the yield from the terminal capsules increased by leaving the lateral capsules unlanced. Similarly the yield of latex from the lateral capsules is not increased by leaving unlanced the terminal capsules or removing them altogether. When, however (*see* plot E), the terminal capsules are first lanced, the yield of latex subsequently obtained by lancing the lateral capsules on the same plants appears to be considerably diminished.

Experiments were carried out in the season 1917-18 to check the foregoing results on a large scale at Cawnpore. Mr. Leake had many hundreds of pure races of poppy growing in small plots. These were being grown so that we could examine the morphine content of opium of each with a view to the isolation of races of poppy giving opium of high morphine content. On certain of these plots all the plants had large numbers of capsules. On 50 such plots the terminal capsules were first lanced and the number of capsules

lanced counted. When sufficient lateral capsules were ready for lancing they were also lanced and counted. In all the plots more terminal capsules came to maturity for lancing after the first lancing, and these were again counted and lanced. The opium of each collection was then examined for loss on drying in the water oven, and for morphine content. The table expresses the results in grm. of dry opium per 1,000 capsules, and also states the percentage of morphine in the opium produced.

Plot No.	Terminal capsules					Lateral capsules				
	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules
148	26–2–18	16·60	201	12·5	83·9	5–3–18	21·60	389	9·6	55·5
	4–3–18	21·73	96	12·5	220·6					
149	26–2–18	15·75	228	12·3	69·1	5–3–18	28·25	410	10·8	69·0
	4–3–18	19·07	286	12·3	66·7					
150	26–2–18	2·83	67	11·9	42·5	5–3–18	13·98	191	10·5	73·2
	4–3–18	26·20	466	12·3	56·2					
151	28–2–18	13·44	164	12·4	82·0	5–3–18	14·37	231	10·5	62·2
	4–3–18	13·54	240	12·4	56·3					
158	26–2–18	18·61	224	12·0	83·8	5–3–18	13·76	169	9·2	81·4
	4–3–18	18·76	338	12·7	55·8					
159	28–2–18	21·72	241	10·6	90·1	5–3–18	12·12	123	9·4	98·5
	4–3–18	26·35	511	18·2	49·5					
160	28–2–18	36·36	411	10·8	88·5	5–3–18	23·96	423	8·7	56·7
	4–3–18	23·90	421	12·4	56·8					
161	28–2–18	7·97	140	10·2	57·0	5–3–18	11·46	224	10·0	51·1
	4–3–18	1·80	11	..	164·0					
162	28–2–18	45·25	598	12·8	75·7	5–3–18	24·75	564	9·9	43·9
	4–3–18	10·30	160	11·8	64·4					
163	28–2–18	32·18	374	12·6	86·0	5–3–18	25·20	551	10·1	45·7
	4–3–18	15·5	329	12·3	47·3					

Plot No.	Terminal capsules					Lateral capsules				
	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules
164	28–2–18	34·90	306	12·3	114·1	5–3–18	21·86	351	10·3	62·3
	4–3–18	14·59	267	11·5	54·7					
165	28–2–18	20·72	296	13·4	70·0	5–3–18	18·03	306	11·5	58·9
	4–3–18	12·75	286	13·3	44·7					
166	28–2–18	24·53	475	13·0	51·7	5–3–18	21·67	229	10·5	94·6
	4–3–18	8·01	312	12·8	25·6					
167	28–2–18	19·22	202	11·7	95·1	5–3–18	15·13	266	10·5	56·9
	4–3–18	19·36	421	11·9	46·1					
168	28–2–18	18·92	257	11·8	73·6	5–3–18	11·83	210	8·8	56·3
	4–3–18	19·32	341	11·5	56·6					
169	28–2–18	23·24	394	12·6	59·0	5–3–18	12·75	239	10·5	53·3
	4–3–18	10·33	333	12·1	31·0					
170	28–2–18	31·15	358	12·1	87·0	5–3–18	25·70	505	9·5	50·9
	4–3–18	14·28	268	11·8	53·3					
171	28–2–18	31·78	382	12·0	83·0	5–3–18	22·98	439	9·9	52·3
	4–3–18	11·92	271	12·0	44·0					
172	28–2–18	22·00	181	12·8	121·5	5–3–18	16·14	146	10·5	110·6
	4–3–18	21·17	400	13·0	50·3					
173	28–2–18	34·89	430	12·0	81·2	5–3–18	22·70	358	10·3	63·4
	4–3–18	4·68	297	11·6	15·6					
174	28–2–18	5·93	60	11·4	98·9	5–3–18	26·07	214	10·5	121·8
	4–3–18	8·20	275	12·0	30·0					
175	19–2–18	9·86	291	12·6	33·9	5–3–18	22·63	568	9·5	39·8
	4–3–18	17·64	102	12·5	175·0					
176	19–2–18	6·26	200	13·5	31·3	5–3–18	19·00	579	12·2	32·8
	4–3–18	5·60	182	13·1	31·0					

Plot No.	Terminal capsules					Lateral capsules				
	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium 1,000 per capsules
177	19–2–18	3·22	73	11·9	44·8	5–3–18	27·83	594	10·2	46·8
	4–3–18	31·16	391	12·8	80·0					
178	26–2–18	34·55	596	10·7	58·0	5–3–18	21·63	646	8·5	33·5
	4–3–18	10·31	..	13·1	..					
179	26–2–18	34·38	591	11·4	58·2	5–3–18	14·20	459	9·4	30·7
	4–3–18	8·02	262	12·5	30·6					
180	26–2–18	21·91	713	12·9	30·7	5–3–18	14·76	376	10·9	39·2
	4–3–18	4·15	163	12·0	25·4					
181	26–2–18	21·86	674	13·1	32·4	5–3–18	9·84	317	9·9	31·0
	4–3–18	5·53	261	13·0	21·2					
182	26–2–18	26·02	598	12·5	44·0	5–3–18	11·49	291	10·1	39·5
	4–3–18	6·34	259	12·7	24·1					
183	28–2–18	20·42	580	12·2	35·2	5–3–18	9·60	343	9·7	28·0
	4–3–18	6·08	229	12·5	27·0					
184	28–2–18	17·56	319	11·7	55·1	5–3–18	12·40	343	9·5	36·2
	4–3–18	18·65	310	12·4	60·1					
185	28–2–18	14·80	360	11·1	41·2	5–3–18	10·28	686	9·3	15·0
	4–3–18	3·60	89	9·2	40·4					
186	28–2–18	41·32	599	12·0	69·0	5–3–18	19·14	294	9·4	65·2
	4–3–18	7·80	194	11·8	40·2					
187	19–2–18	8·57	422	14·7	20·3	5–3–18	14·96	487	12·3	30·7
	4–3–18	9·31	295	13·2	31·6					
188	19–2–18	8·23	221	13·0	36·7	5–3–18	15·7	503	10·9	31·2
	4–3–18	11·6	362	13·4	31·8					
189	19–2–18	6·81	123	12·4	56·2	5–3–18	21·5	534	10·2	40·3
	4–3–18	12·7	384	12·2	33·1					

Plot No.	Terminal capsules					Lateral capsules				
	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules	Date of lancing	Grm. dry opium	No. of capsules lanced	Percentage of morphine in dry opium	Grm. dry opium per 1,000 capsules
190	27–2–18	15·42	257	10·6	60·0	5–3–18	14·42	354	8·8	40·8
	4–3–18	4·07	118	10·8	34·5					
191	27–2–18	23·79	369	10·9	64·4	5–3–18	13·08	304	9·4	43·0
	4–3–18	6·65	204	10·8	32·1					
192	26–2–18	15·85	291	10·9	54·4	5–3–18	7·15	292	8·1	33·4
	4–3–18	11·85	277	10·3	42·8					
193	26–2–18	12·55	312	10·8	40·2	5–3–18	14·18	453	9·7	31·3
	4–3–18	6·02	350	10·9	17·2					
194	26–2–18	8·76	122	11·4	71·8	5–3–18	15·08	435	8·9	34·6
	4–3–18	16·70	459	11·3	36·4					
195	27–2–18	17·81	500	11·8	35·6	5–3–18	17·64	437	9·6	40·3
	4–3–18	2·10	131	11·1	16·0					
196	27–2–18	13·97	540	12·8	25·9	5–3–18	9·50	278	9·7	34·1
	4–3–18	2·40	114	10·7	21·1					
197	27–2–18	26·47	526	12·1	50·3	5–3–18	9·44	303	9·2	31·1
	4–3–18	4·97	203	11·9	24·5					
198	27–2–18	18·32	556	12·4	33·0	5–3–18	11·19	475	11·7	23·6
	4–3–18	0·80	83	..	9·6					
199	27–2–18	32·06	493	11·8	65·2	5–3–18	17·60	552	9·0	31·9
	4–3–18	9·34	314	11·6	29·4					
200	27–2–18	21·69	480	11·5	45·0	5–3–18	11·94	440	10·4	27·2
	4–3–18	8·60	132	10·8	..					
201	27–2–18	13·15	194	9·5	67·8	5–3–18	10·03	492	9·0	20·4
	4–3–18	1·80	79	..	22·8					
202	27–2–18	17·87	225	11·7	79·4	5–3–18	15·17	413	9·5	36·7
	4–3–18	4·20	105	11·1	40·0					
203	27–2–18	16·31	181	10·2	90·0	5–3–18	20·72	459	10·0	45·1
	4–3–18	5·94	132	10·8	45·0					

The above table affords ample confirmation of the fact that lateral capsules on a plant produce opium of lower morphine content than the terminal capsules do. Out of the 50 plots examined not one has given opium from its lateral capsules higher in morphine content than that from its terminal capsules. The lancing of terminal capsules which appeared on later maturing plants in each plot provided a check on the experiment. The opium from both crops of terminal capsules showed, in the majority of cases, practically identical morphine content and this does away with the possibility that the lateral capsules gave opium of lower morphine content because they were lanced later in the season. Moreover, it will be seen later that, after the capsule has passed the soft stage, practically no change takes place in the morphine content of the latex from the first lancing.

As regards the yield of opium from the lateral capsules the figures are not so conclusive. Certainly, in the majority of cases, the lateral capsules seem to have yielded less opium than the terminal ones, but there are, on the other hand, many cases in which the lateral capsules have given a greater yield than the terminal ones.

It would seem that by removing all lateral capsules from a plant the yield of latex from the terminal capsule is increased. This is borne out by the following experiment carried out in 1917-18. An area of $\frac{1}{2}$ acre was divided at flowering time into 4 equal plots (*a*), (*b*), (*c*), and (*d*). On plots (*a*) and (*c*) all lateral flower buds were removed as soon as they were formed, whereas on plots (*b*) and (*d*) the plants were allowed to produce as many capsules as they were able to. On the occasion of the first lancing, all the capsules lanced in each plot were counted. The capsules received three vertical cuts at each lancing and three successive lancings were carried out. The table sets out the results.

No. of lancing	PLOT (*a*) ALL LATERAL BUDS REMOVED		PLOT (*b*) NO BUDS REMOVED		PLOT (*c*) ALL LATERAL BUDS REMOVED		PLOT (*d*) NO BUDS REMOVED	
	Total dry opium per 1,000 capsules grm.	Percentage of morphine in dry opium	Total dry opium per 1,000 capsules grm.	Percentage of morphine in dry opium	Total dry opium per 1,000 capsules grm.	Percentage of morphine in dry opium	Total dry opium per 1 000 capsules grm.	Percentage of morphine in dry opium
1st	83·3	14·1	51·0	14·2	70·3	14·6	46·3	13·9
2nd	22·6	7·8	18·4	9·7	31·6	9·7	10·7	10·7
3rd	6·9	6·6	6·5	5·4	19·6	4·8	6·0	6·6

The yield of opium per 1,000 capsules is in each case much greater from the plots in which all lateral buds were picked off, this being especially marked in the product of the first lancing. It may, of course, be that a number of lateral capsules were included in the first lancings of plots (*b*) and (*d*). Since it has been shown that lateral capsules usually yield less opium than terminal ones, this might account for the lower yield per 1,000 capsules in plots (*b*) and (*d*). Unfortunately no record was made of the number of lateral capsules included in the lancings of plots (*b*) and (*d*). Since the lateral capsules come to maturity later than the terminal ones in the same plant, it is improbable that there could have been enough lateral capsules lanced in plots (*b*) and (*d*) to account for such a large difference in yield from that in plots (*a*) and (*c*). It therefore seems strongly indicated that the removal of lateral buds results in a bigger yield of latex by the remaining terminal capsules. If one aims at single-capsuled plants, it is therefore likely that they will be good yielders. This is an important point from the point of view of the production of high morphine content opium.

Conclusions.

1. The terminal or oldest capsules of a plant produce opium of considerably higher morphine content than the lateral capsules do. Hence to produce opium of high morphine content, one should endeavour to grow plants with single capsules. For any particular plant bearing many capsules the indications are that the morphine content of its opium falls off in the order of origin of the capsules.

It would appear that the inferiority of the opium from lateral capsules in morphine content has not been discovered by the Turks. In the *Encyclopædia Britannica*[1], it is stated with reference to Turkey that "the capsules are generally incised only once but the fields are visited a second or third time to collect the opium from the poppy heads subsequently developed by the branching of the stem."

2. As regards the out-turn of opium, terminal capsules usually produce more opium than lateral capsules and this is a further reason for growing plants with only a single capsule. By removing lateral capsules it would appear that the opium yield of the remaining terminal capsules can be considerably increased. Since it is shown later, in the account of the effect of manure on the alkaloidal content of opium, that, for a particular race of poppy, the yield of opium is proportional to the size of the capsule, the present conclusion

[1] Article on "Opium," 11th Edn., page 131.

is what one might expect. By removing lateral capsules the remaining terminal one might be expected to reach a larger size and in this way the larger yield of opium would be accounted for.

THE INFLUENCE OF THE AGE OF THE CAPSULES.

It has been shown previously[1] that, when a capsule is lanced on consecutive days, or on every second or third day, the opium of the first lancing is richest in morphine, and that the opium from each successive lancing shows a regular decrease in its morphine content. It was there remarked (p. 15) that a possible explanation of this falling off in morphine content of the opium of each successive lancing might be that the morphine content of the capsule decreased during ripening. The work here described will, however, show that this explanation is inadmissible.

A review of the literature indicates that a certain amount of work has been done on the alkaloidal content of poppy capsules, at various stages of ripeness. Malin[2] carried out some experiments to determine the alkaloidal content of ripe and unripe poppy capsules. The stage of ripeness is not clearly defined. Malin states that the unripe capsules taken were from two harvests of 12th and 16th August 1905 respectively. The former were still distinctly green and those of the second harvest were scarcely noticeably riper. Malin also took unlanced ripe capsules from the fields on 17th September. Using somewhat unsatisfactory methods of analysis he obtained the following results :—

Date of harvesting	Percentage of morphine	Percentage of narcotine plus codeine
Unripe capsules harvested 12th August	0·050	0·0113
„ „ „ 16th August	0·020	0·0116
Fully ripe „ „ 17th September	0·018	0·0280

Malin considers that these figures show that, during the ripening of the poppy capsule, the morphine diminishes, and the narcotine and codeine increase.

[1] Annett, Sen, and Singh. *Mem. Dept. Agri. India, Chem. Ser.*, vol. VI, no. 1 (pt. III).

[2] Thoms. *Uber Mohnbau and Opiumgewinnung*, p. 59, Berlin, 1907.

Tromsdorff[1] states that one year old ripe capsules contain neither morphine nor narcotine. Winkler[2] states that morphine and narcotine are present in fully ripe poppy capsules.

Merck[3] obtained 18 grains of morphine from 32 oz. of poppy capsules (roughly 0·0075 per cent.). Cæsar and Loretz[4] in 1901 found 0·0189 per cent. morphine in fully ripe poppy capsules.

Muller[5] in an interesting paper states that, in plants grown under natural conditions, the amount of alkaloid in the capsules, stems, and leaves, diminishes, but does not completely disappear as the seed ripens. When the plants were removed from the soil at the flowering stage, and then grown in non-nitrogenous nutrient solutions, the alkaloidal content of the whole plant had diminished after 10 days. After 48 days, when the seed had ripened, the leaves and stems were quite free from alkaloids, and the capsule walls contained traces of alkaloids which could only be detected qualitatively, and were too small to be estimated.

The present writer has examined capsules which were harvested at the lancing stage but without having been lanced. They were dried in the sun, and the air-dried capsules after one year's storage yielded 0·645 per cent. of morphine and 0·018 per cent. of codeine calculated on the dry matter. The amount of alkaloids found depends much on the methods of investigation used. Accurate methods of estimating small amounts of morphine, codeine or narcotine in large quantities of plant material have been worked out in the writer's laboratory, and a description of them is being published elsewhere.

It is of interest that, where poppies are grown for their capsules, *e.g.*, in the Isle of Axholme in England, they are harvested well before they are dead ripe.

It is perhaps worth while to refer here to some of the literature bearing on the alkaloidal content of certain other medicinal plants at various stages of ripeness. In the *Year Book of Pharmacy* for 1914[6] the following passage occurs :—

" Farr and Wright's results seem to indicate that coniine present in hemlock may take part in the formation of the proteid reserve food found in the fruit. The amount of alkaloid found in the root, stem and leaves is small,

[1] *Archiv der Pharm.*, XXXVIII, p. 231.
[2] Ann. IV, page 237. Through Thoms. *loc. cit.*, p. 60.
[3] Ann. IV, page 237. Through Thoms. *loc. cit.*
[4] Thoms. *loc. cit.*, p. 60.
[5] *Archiv der Pharm.* 252, 1914, pp. 280-293.
[6] Presidential address, p. 314.

while in the fruit it is considerable during the period when the fruit is forming its reserve material, reaching as much as 3 per cent. or even more. When the fruit has finished forming its reserve and ripens, the proportion of alkaloid is found to become less, not greater, until it falls off to less than 1 per cent. in the ripe fruit. Moreover, the proportion of alkaloidal to total nitrogen gradually diminishes as the fruit develops. If the alkaloid were a by-product in the production of proteid, it might be expected to retain a fairly constant ratio and not become a diminishing one."

Carr[1] states that, when the belladonna plant begins to fade, there is a rapid loss of alkaloid in the stem and leaves.

Carr[2] also records cases showing the influence of advance of season on the amount of active principles in certain drugs. The following results were obtained with broom tops gathered month by month from the same locality throughout the year :—

Month	Percentage of sparteine sulphate
August	0·07
September	0·17
October	0·34
November	0·48
December	0·56
January	0·36
February	0·36
March	0·53
April	0·44
July	0·23

Carr concludes that there is a rapid loss of alkaloid during the flowering and growing period, which is slowly replaced during the quiescent months of autumn and winter.

Experimental.

At Almorah in the season 1916-17 two sets of plants were marked, one with capsules a little beyond the stage at which the cultivators take them

[1] International Congress of Applied Chemistry. "Effect of Cultivation on Alkaloidal Content of Belladonna." Through *Chem. and Drugg.*, 1912, 81, p. 432.

[2] Carr and Reynolds. *Pharm. Journ.*, IV, 26, p. 543.

for lancing, the other with the capsules green and soft, that is, at least a week earlier than the cultivators would use them. There were 499 plants in the first group, and 498 in the second. The capsules were lanced in the ordinary way and each received subsequent lancings as long as they yielded opium. The date of lancings and other details are set out in the table.

No. of lancing	Immature capsules					Overmature capsules				
	Date of lancing	No. of capsules lanced	Dried opium grm.	Dried opium per 1,000 capsules grm.	Percentage of morphine in dry opium	Date of lancing	No. of capsules lanced	Dried opium grm.	Dried opium per 1,000 capsules grm.	Percentage of morphine in dry opium
1st	20–4–17	498	6·80	13·60	8·94	29–4–17	499	12·40	24·85	13·28
2nd	23–4–17	498	5·55	11·14	6·44	2–5–17	499	10·55	21·14	10·20
3rd	26–4–17	498	5·60	11·24	4·61	10–5–17	342	4·40	12·87	5·01
4th	27–4–17	498	2·80	5·82	1·70	12–5–17	226	2·10	9·29	2·85
5th	2–5–17	498	3·50	7·03	1·25					
6th	10–5–17	290	2·02	6·96	1·25					
7th	12–5–17	190	1·05	5·52						

The results obtained would indicate fairly definitely that, if the capsules are taken in too young a stage, not only do they yield appreciably less opium, but this opium contains much less morphine reckoned on the dry substance. One must be very cautious in drawing general conclusions from a single experiment in this kind of work, for there may be so many other factors involved, *e.g.*, weather conditions for one, and it was not possible to find sufficient plants to make up two groups on the same day.

1917-18 Experiments.

In the season 1917-18 arrangements were made to investigate the questions more in detail at Cawnpore. The plan of this experiment was to collect opium from capsules in different stages of development. In order to do this, it was necessary to make sure of the age of the capsules chosen. The field used had been sown with a pure race of poppy. Its area was 0·85 acre. The original idea was to take some 20,000 plants in this field which were at the same stage on a particular day. The stem bearing the bud straightens out in the case of the poppy the day before the flower opens, and the buds were selected at this stage. As far as possible plants showing only one bud were chosen.

Any lateral buds subsequently appearing were carefully removed. These 20,000 plants were to be divided into six groups of roughly 3,000 plants each, and the plants of each group labelled with cloth labels of a distinguishing colour for each group. It was then proposed to collect opium from each group at different ages. This programme was adhered to except that it was found impossible to label the whole of the plants on one day. All the plants were however labelled at the same stage, *i.e.*, the day before the buds would burst into flower. The plants were most carefully checked and those few plants which, after labelling, did not burst into flower next day, were discarded from the experiment. The age of all the capsules was thus known with certainty to within one day. The table explains the arrangement of the experiments. Two successive lancings were taken from the capsules of each group :—

No. of group	Distinctive group label	No. of plants in group	Date of labelling	Date of lancing		Age of capsules in days from flowering
				First	Second	
1	Red cloth	3,500	11–2–18	17–2–18	19–2–18	6
2	White cloth	3,250	7–2–18	18–2–18	20–2–18	11
3	Paper labels	3,125	12–2–18	28–2–18	2–3–18	16
4	Khaki cloth	3,250	14–2–18	7–3–18	9–3–18	21
5	Black cloth	3,500	15–2–18	13–3–18	15–3–18	26
6	Yellow cloth	3,375	16–2–18	19–3–18	21–3–18	31

To simplify the counting, the field had been divided by means of rope into ten sub-plots. The plants of each group were fairly uniformly distributed over the whole area, in order to rule out as far as possible any effect which might arise owing to want of uniformity of soil, moisture, etc. Further the opium was collected from each group in several samples. The produce of each sample was analysed separately, and the number of plants yielding each sample was separately recorded. In this way an idea could be obtained of the error of the experiment. Moreover, as a further check on the work, on each day on which the plants of a group were first lanced we selected 1,000 capsules which the cultivators considered ready for lancing, and lanced these. Unfortunately, this control was omitted with group 1 and was deliberately omitted with group 4, because the cultivators considered that the capsules of the group lanced that day were at the correct stage for lancing.

Table showing effect of stage of ripeness of capsules on morphine content of opium produced, 1917-18 *experiments.*

No. of group	Distinctive label and date of 1st lancing. 2nd lancing two days later	No. of days between flowering and 1st lancing	First lancing					Second lancing				
			No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.	No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.
1	Red cloth 17–2–18	6	1	1,500	10·8	65·57	43·7	1	1,476	6·4	14·86	10·1
			2	1,250	11·0	72·98	58·3	2	1,196	6·6	11·80	9·9
			3	870	10·9	47·12	54·2	3	820	5·5	8·78	10·7
				3,620 Total	10·9 Average	185·67 Total	52·1 Average		3,492 Total	6·2 Average	35·44 Total	10·2 Average
2	White cloth 18–2–18	11	1	625	12·7	30·55	48·9	1	612	6·0	14·35	23·0
			2	681	12·6	33·60	49·3	2	671	7·2	11·28	16·0
			3	672	13·4	33·00	49·1	3	695	7·2	12·40	17·8
			4	599	12·7	28·71	47·9	4	588	4·6	7·60	12·9
			5	618	13·2	31·29	50·6	5	601	5·0	8·60	14·3
				3,195 Total	12·9 Average	157·15 Total	49·2 Average		3,167 Total	6·0 Average	54·23 Total	16·9 Average
	18–2–18	Control	1	510	12·4	33·81	66·3	1	511	6·1	11·04	21·6
			2	465	13·3	26·34	56·6	2	470	6·5	8·88	18·9
				975 Total	12·8 Average	60·15 Total	61·5 Average		981 Total	6·3 Average	19·92 Total	20·2 Average

3	Paper labels 28–2–18	16	1	652	12·9	37·21	50·2	1	619	6·1	5·55	9·0
			2	741	12·5	39·72	53·6	2	711	6·6	6·44	9·0
			3	879	12·2	48·14	54·8	3	902	6·7	7·74	8·8
			4	748	13·3	46·38	62·0	4	780	6·8	8·49	11·3
				3,020 Total	12·7 Average	171·45 Total	55·1 Average		3,012 Total	6·5 Average	28·22 Total	9·5 Average
	28–2–18	Control	1	698	12·0	58·73	84·1	1	698	7·9	8·99	12·8
			2	648	13·4	53·16	82·0	2	648	7·0	13·46	20·8
			3	589	13·1	40·01	67·9	3	588	7·4	8·22	14·0
				1,935 Total	12·8 Average	151·90 Total	78·0 Average		1,934 Total	7·4 Average	30·67 Total	15·8 Average
4	Khaki cloth 7–3–18 (No control carried out)	21	1	1,015	13·6	45·34	44·7	1	910	8·0	6·67	6·6
			2	1,041	12·3	37·00	35·6	2	999	6·6	3·50	3·5
			3	1,019	14·1	49·82	48·9	3	1,003	8·3	12·8	8·49
				3,075 Total	13·3 Average	132·16 Total	43·1 Average		2,912 Total	7·6 Average	20·11 Total	7·4 Average
5	Black cloth 13–3–18	26	1	1,140	14·8	33·06	29·0	1	1,138	9·2	6·07	5·3
			2	1,085	14·7	33·66	31·0	2	1,052	10·1	6·18	5·7
			3	1,141	13·5	34·29	30·4	3	1,101	8·7	4·61	4·2
				3,366 Total	14·3 Average	101·01 Total	30·1 Average		3,291 Total	9·3 Average	16·81 Total	5·1 Average
	13–3–18	Control	1	500	14·0	29·05	58·1	1	500			
			2	150	13·9	8·97	59·8	2	150	7·1 *	3·06	3·1
			3	350	14·5	21·19	60·5	3	350			
				1,000 Total	14·1 Average	59·21 Total	59·2 Average		1,000 Total			
6	Yellow cloth 18–3–18	31	Capsules over-ripe and yielded no latex.									

* Total of three samples combined since insufficient for separate analyses.

Note.—The number of capsules lanced at the second lancing does not agree exactly with the number lanced at the first lancing. This is chiefly due to the difficulty of counting so many plants in the field accurately.

In reviewing these figures, it appears that the morphine content of the opium of young soft green capsules, such as were used for lancing in group 1, is distinctly lower than that of the opium of riper capsules. When however, as in group 2, the capsules are lanced 11 days after the opening of the flower, the morphine content of the opium is about equal to that from the capsules lanced on the same day at the stage the cultivators considered ready for lancing. Even when the capsules are lanced as in group 5, *i.e.*, 26 days after the flower opens, there is no falling off in the morphine content of the opium, but rather an increase. It is of interest to observe, however, that in the control capsules lanced with groups 2 and 3, the morphine content of the opium is distinctly lower than that of the control capsules lanced with group 5. Moreover, among the groups themselves group 5 has yielded the highest morphine content of opium. The results are shown graphically in Chart II.

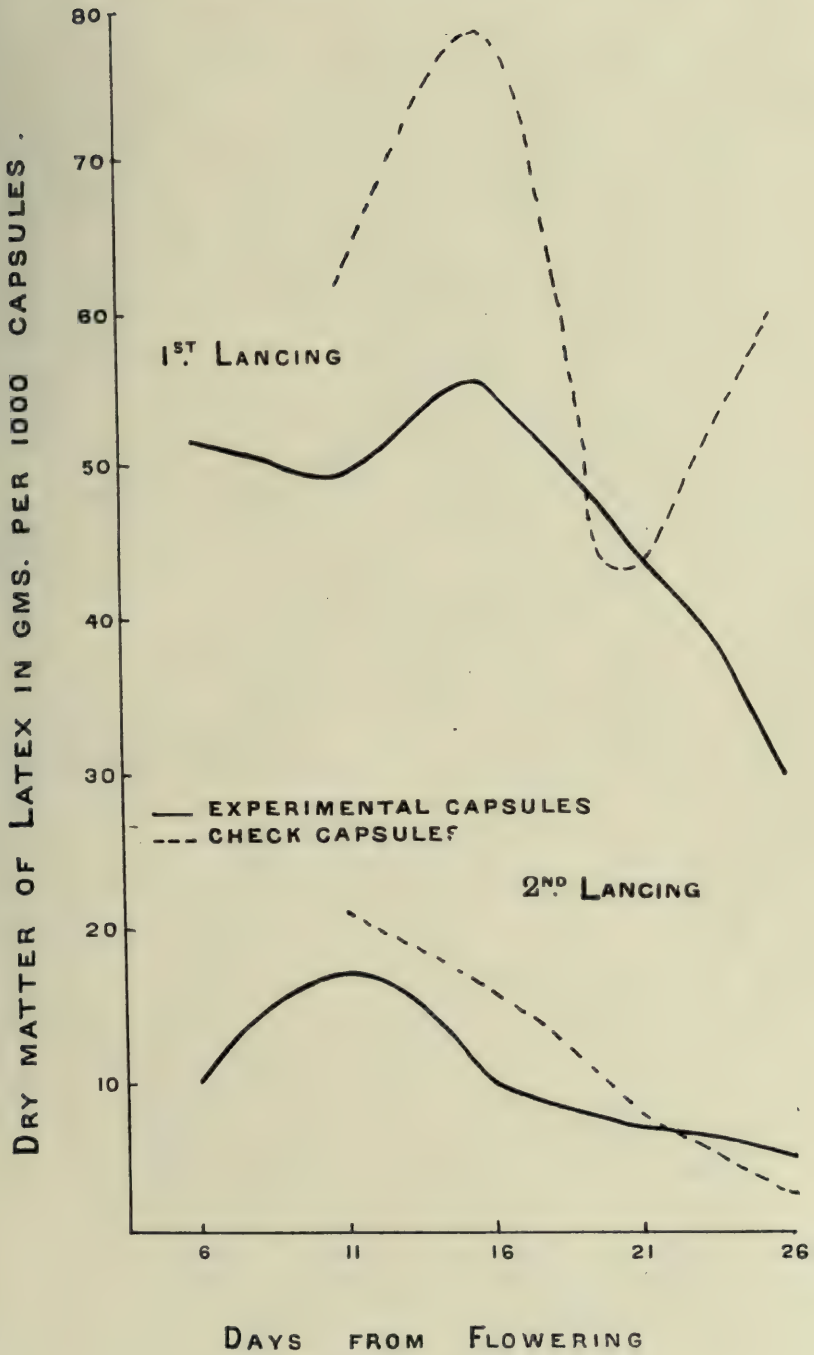
As regards the yield of opium per 1,000 capsules, this has proved more or less constant in the three control series carried out with groups 2, 3, and 5. In the groups, however, it has reached its maximum with group 3, *i.e.*, with capsules lanced 16 days after flowering. With group 5, however (capsules lanced 26 days after flowering), the yield per 1,000 capsules seems to fall off considerably. This is well illustrated in Chart I.

1918-19 Experiments.

In the season 1918-19, the experiment was repeated at Cawnpore. The plan of the experiment was the same as in the previous year, but its execution was more satisfactory in that the selected plants were all labelled on the same day at the same stage; moreover, a control lancing of capsules at the correct lancing stage was made on each day on which experimental capsules were lanced and further there were seven groups of plants, the first group being lanced five days from flowering, and each successive group being lanced at four days' intervals. There was an important difference from the previous year's experiment as regards method of lancing adopted. In 1917-18 three vertical incisions were made at each lancing instead of the usual one made by the cultivators. In 1918-19 the ordinary method of a single incision with a 3-bladed knife was used. This difference in lancing should be borne in mind in considering the curves for yield of opium, since, as has been shown[1], the method of lancing influences the yield of opium. The 1918-19 results are fully set out in the next table and they are illustrated graphically in Charts III and IV.

[1] Annett, Sen, and Singh. *Mem. Dept. Agri. India, Chem. Ser.*, vol. VI, no. 1 (pt. V).

Effect of age of capsules on Latex yield 1917-1918.



Effect of age of capsules on morphine content of latex 1917-1918.

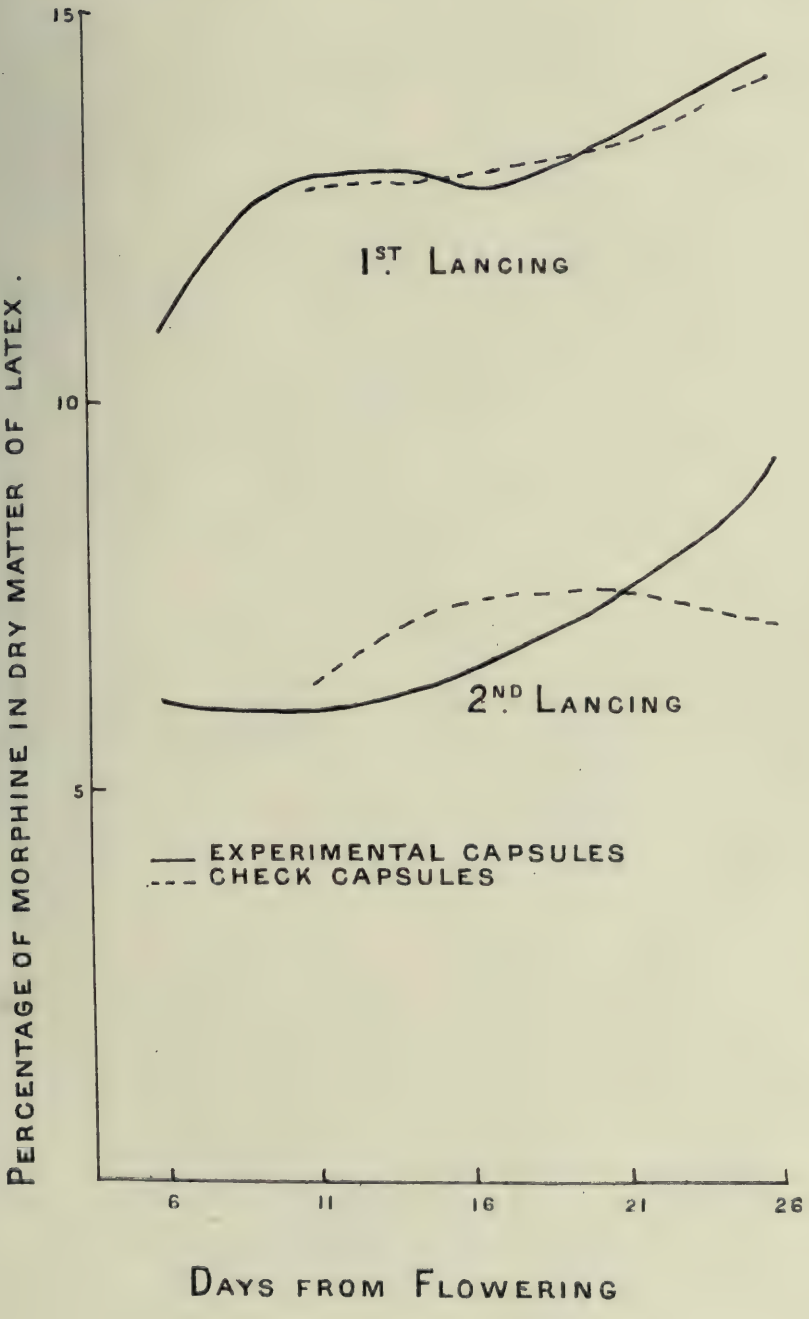


Table shewing effect of stage of ripeness of capsules on morphine content of opium produced, 1918-19 *experiments.*

No. of group	Distinctive label and date of 1st lancing. 2nd lancing two days later	No. of days between flowering and 1st lancing	First lancing					Second lancing				
			No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.	No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.
1	White labels 22–2–19	5	1	675	9·8	19·30	27·70	1	665	6·3	15·49	23·05
			2	704	10·6	18·88		2	681	6·7	16·30	
				1,379 Total	10·2 Average	38·18 Total			1,346 Total	6·5 Average	31·79 Total	
	22–2–19	Control	1	280	11·2	11·3	40·36	1	267	6·3	6·92	24·72
2	Blue labels 26–2–19	9	1	650	11·1	17·28	28·24	1	645	8·1	11·82	19·69
			2	661	12·2	19·75		2	644	8·6	14·00	
				1,311 Total	11·7 Average	37·03 Total			1,289 Total	8·4 Average	25·82 Total	
	26–2–19	Control	1	612	12·3	15·92	26·01	1	604	7·2	18·06	29·51
3	Purple labels 2–3–19	13	1	614	11·8	16·46	30·40	1	615	8·4	14·53	26·08
			2	684	12·5	23·01		2	670	8·3	19·34	
				1,298 Total	12·1 Average	39·47 Total			1,285 Total	8·3 Average	33·87 Total	
	2–3–19	Control	1	485	11·9	20·69	43·08	1	482	7·9	18·01	36·07
			2	602	11·6	26·15		2	588	7·9	21·20	
				1,087 Total	11·7 Average	46·84 Total			1,070 Total	7·9 Average	39·21 Total	

Table shewing effect of stage of ripeness of capsules on morphine content of opium produced, 1918-19 *experiments.*

No. of group	Distinctive label and date of 1st lancing. 2nd lancing two days later	No. of days between flowering and 1st lancing	First lancing					Second lancing				
			No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.	No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.
4	Red labels 6-3-19	17	1	509	11·4	17·02	36·92	1	488	8 2	10·25	21·10
			2	585	11·5	23·37		2	566	9·2	12·84	
				1,094 Total	11·4 Average	40·39 Total			1,054 Total	8·7 Average	23·09 Total	
	6-3-19	Control	1	519	11·6	22·95	44·51	1	516	8·0	13·28	25·57
			2	478	13·0	21·43		2	474	8·4	12·21	
				997 Total	12·3 Average	44·38 Total			990 Total	8·2 Average	25·49 Total	
5	Black labels 10-3-19	21	1	565	12·1	17·95	26·29	1	571	10·4	10·57	22·13
			2	617	12·8	13·14		2	621	11·0	15·59	
				1,182 Total	12·5 Average	31·09 Total			1,192 Total	10·7 Average	26·16 Total	
	10-3-19	Control	1	520	12·4	19·76	42·76	1	519	9·9	19·45	42·44
			2	509	13·4	24·22		2	510	10·2	24·21	
				1,029 Total	12·9 Average	43·98 Total			1,029 Total	10·0 Average	43·66 Total	

6	Pink labels 14–3–19	25	1	542	12·6	9·34	22·14	1	539	8·6	6·65	16·94
			2	561	12·4	15·07		2	556	9·6	12·04	
				1,103 Total	12·5 Average	24·41 Total			1,095 Total	9·1 Average	18·69 Total	
	14–3–19	Control	1	510	11·6	21·17	44·27	1	510	8·0	20·69	39·73
			2	490	12·7	23·10		2	490	7·7	19·04	
				1,000 Total	12·1 Average	44·27 Total			1,000 Total	7·9 Average	39·73 Total	
7	Yellow labels 18–3–19	29	1	496	12·0	13·57	25·34	1	423	10·4	8·43	8·43
			2	504	12·5	11·77		2	435			
				1,000 Total	12·3 Average	25·34 Total			858 Total			
	18–3–19	Control	1	510	10·8	25·73	56·64	1	503	8·2	14·34	30·91
			2	490	12·3	30·91		2	477	8·4	16·57	
				1,000 Total	11·6 Average	56·64 Total			980 Total	8·3 Average	30·91 Total	

The results obtained appear therefore to confirm those of the previous year.

The curves on Charts I to IV show clearly that as the capsules ripen off their yield of latex rapidly diminishes yet the morphine percentage in the dry matter of the latex does not fall off. One interesting feature of the curves deserves emphasis here. It will be noticed that the morphine content (Charts II and IV) of the opium of the second lancing increases with age of capsule whereas that of the first lancing does not or is certainly marked. Since the yield of opium from the first lancing diminishes rapidly with age of capsule the connection seems established between this fact and the increase in morphine content of the latex from the second lancing with age of capsule. It appears to be indicated that there is a fixed amount of morphine in the capsules, and if the flow of latex at the first lancing is small then the morphine content of a subsequent lancing will be higher than if the first lancing had given a larger yield of latex.

1919-20 Experiments.

The experiment was repeated for a third season but on a less ambitious scale. About 3,000 terminal flower buds were selected the day before they were due to burst into flower. They were divided into three groups of about 1,000 in each and the respective groups were labelled with yellow, red and white labels. The capsules of each group were lanced at 5, 16 and 25 days from flowering respectively, and three successive lancings were carried out in each case at three days' intervals. On each of the days when the capsules of our experimental group were lanced, the cultivators were asked to select capsules which they considered ready for lancing. These were lanced with the experimental capsules to provide a check on the experiments and the check capsules also received a second and third lancing. As a rule the produce of each group was collected in more than one portion in order to provide an additional check on the experiment. The table explains the results.

These figures call for little remark since they bear out those of the two previous seasons. It seems perfectly well established that the morphine content of the latex is distinctly lower in the case of very young capsules than it is later on, but the morphine concentration of the latex reaches its maximum before the capsules are actually ripe and thereafter does not again fall off.

Effect of age of capsules on latex yield 1918-1919.

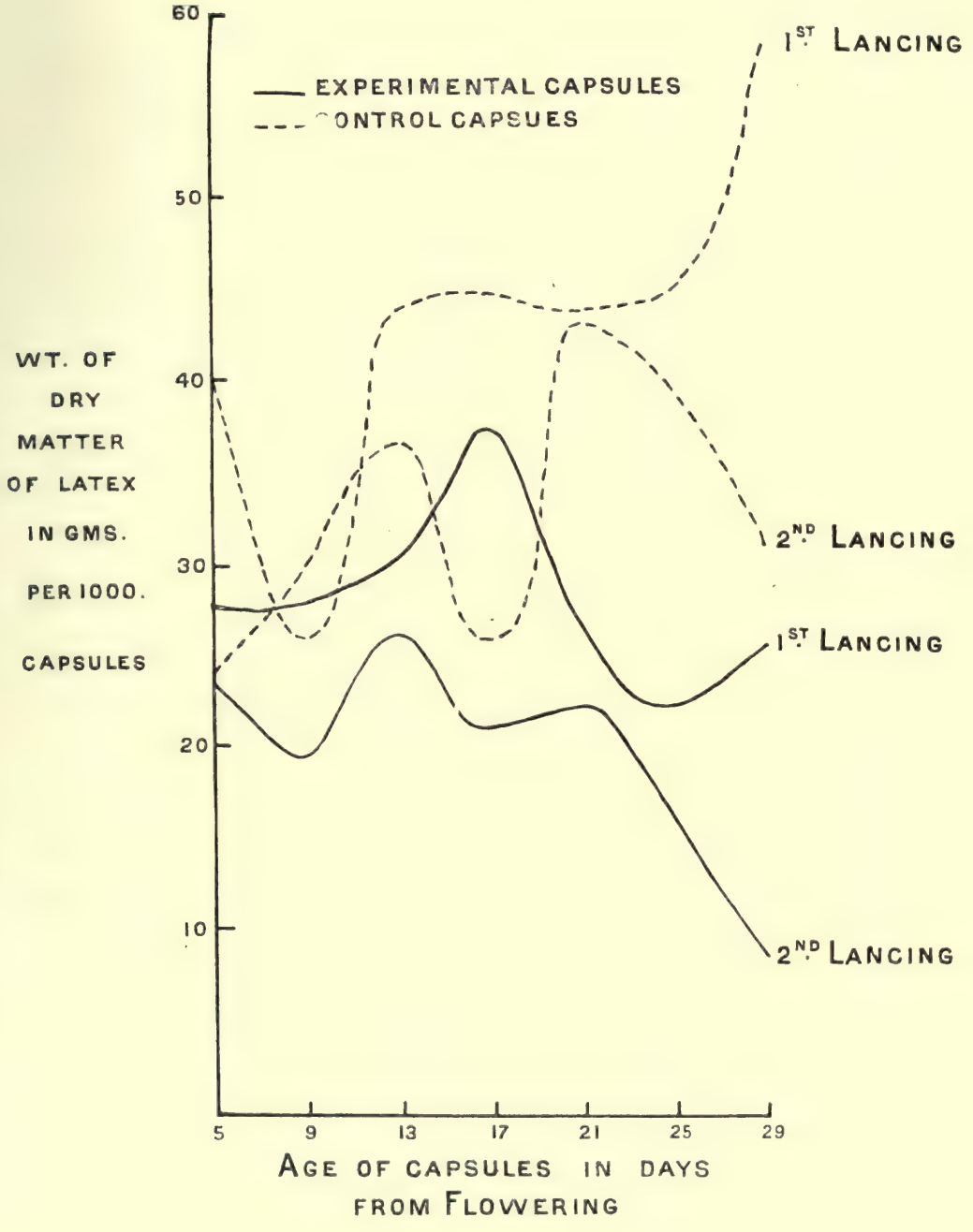
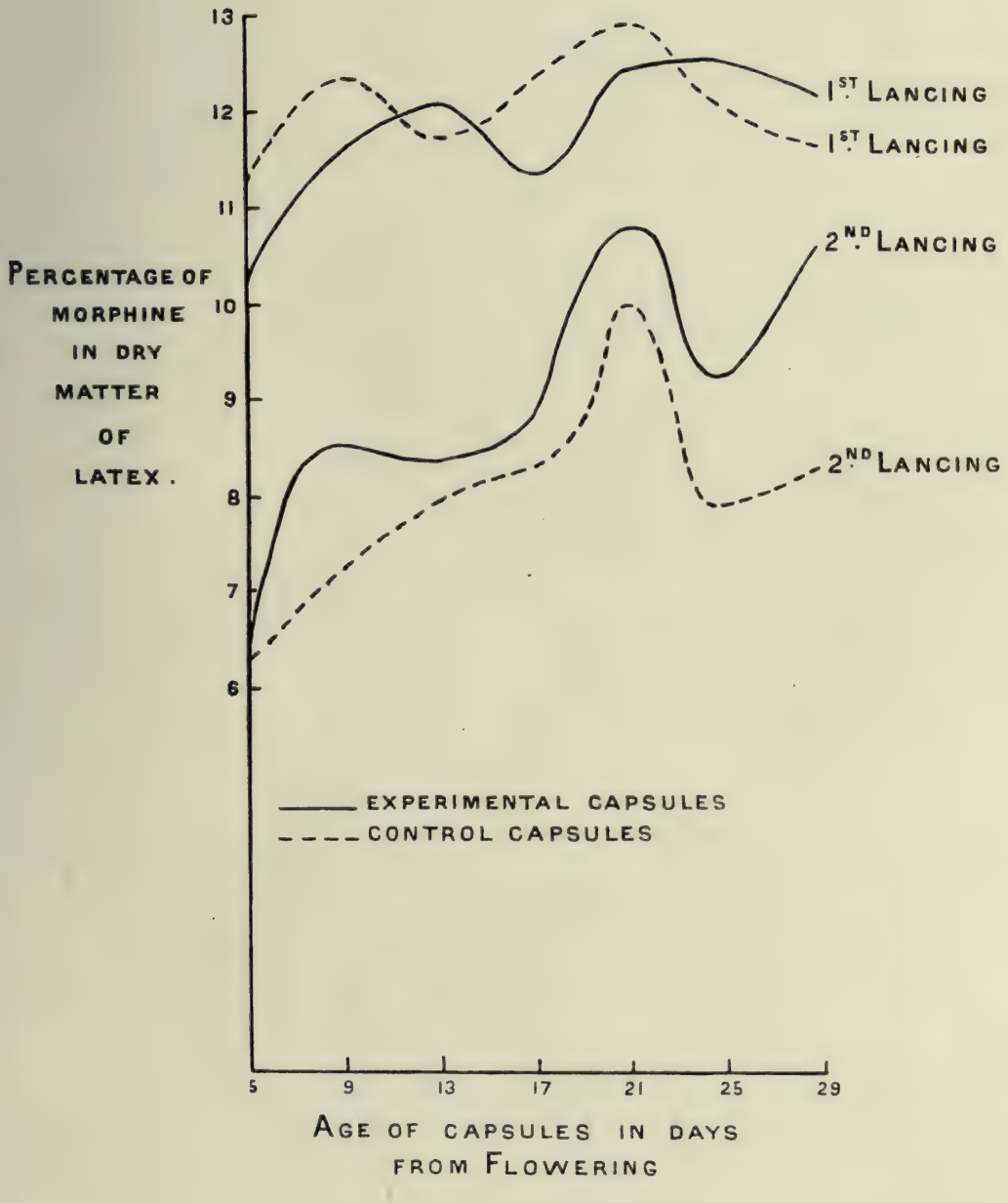


CHART IV.

Effect of age of capsule on morphine content of latex - 1918-1919.



No. of group	Days between flowering and 1st lancing	No. of lancing	Date of lancing	No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.
I	5	First	6–3–20	1	384	11·8	9·84	25·83
				2	327	12·2	10·98	33·58
				3	338	12·7	7·82	23·15
					1,049 Total	12·2 Average	28·64 Total	27·52 Average
		Second	9–3–20	1	388	7·4	5·48	14·29
				2	642	8·2	8·89	12·32
					1,030 Total	7·8 Average	14·37 Total	13·30 Average
		Third	12–3–20	1	377	5·8	9·69	25·82
				2	642	5·1	13·17	19·81
					1,019 Total	5·4 Average	22·86 Total	22·81 Average
	Control	First	6–3–20	1	655	15·0	26·59	40·41
				2	411	16·2	17·18	41·81
				3	400	15·4	14·32	35·79
					1,466 Total	15·5 Average	58·09 Total	39·34 Average
		Second	9–3–20	1	648	11·2	21·43	32·72
				2	411	12·6	13·16	32·03
				3	393	12·0	12·41	31·02
					1,452 Total	11·9 Average	47·00 Total	31·92 Average
		Third	12–3–20	1	632	6·8	12·38	18·91
				2	406	7·3	15·58	37·90
				3	399	6·8	14·68	36·67
					1,437 Total	7·0 Average	42·64 Total	31·16 Average

No. of group	Days between flowering and 1st lancing	No. of lancing	Date of lancing	No. of sample	No. of capsules producing sample	Percentage of morphine in dry opium	Total grm. dry opium	Dry opium per 1,000 capsules grm.
II	16	First	17–3–20	1	458	14·0	8·96	19·56
				2	534	14·6	15·92	29·82
					992 Total	14·3 Average	24·88 Total	24·69 Average
		Second	20–3–20	1	420	11·4	5·91	12·89
				2	512	11·2	8·88	16·63
					932 Total	11·3 Average	14·79 Total	14·76 Average
		Third	23–3–20	1	878	6·4	3·71	3·74
	Control	First	17–3–20	1	600	14·6	25·34	42·23
				2	500	14·6	25·63	51·26
					1,100 Total	14·6 Average	50·97 Total	46·74 Average
		Second	20–3–20	1	500	10·3	12·96	25·92
		Third	23–3–20	1	406	5·0	4·27	8·54
*III	25	First	26–3–20	1	518	16·3	5·79	11·19
	Control	First	26–3–20	1	500	15·1	14·79	29·58

* Note. Heads dried up after 1st lancing.

CONCLUSIONS.

1. Very soft immature capsules, say six days old from the date of flowering, produce opium of lower morphine content than older capsules.

2. Provided they are not less than about eight days old from the date of flowering, the age of the capsule has but little effect on the percentage of morphine in the opium produced.

The probability is, therefore, that as the capsules ripen their morphine content does not decrease as has been stated by other workers.

3. As regards yield of opium per capsule this reached a maximum in our experiments when the capsules were 16-17 days old from the date of flowering. Subsequently the yield of opium per capsule diminished.

THE INFLUENCE OF MANURES.

A review of the literature shows that there is a fairly widespread opinion that the alkaloidal content of plants can be affected by manuring.

Henry[1] states that "the quantity of alkaloid can be greatly increased by special cultivation."

Tunmann[2] states that "the alkaloid content can be increased by suitable manuring, but this effect is only indirect since more robust plants are produced." In this connection he mentions the names of Vanderlinden Feldhaus, Chevalier and Mitlacher.

Work by Wayne Arny[3] on belladonna shows, however, that small plants contained the highest percentage of atropine. It has been stated also that, in the case of indigo, stunted plants contain the highest amounts of the glucoside indican. These facts would appear to lead one to expect bigger plants from manuring with consequent lower percentages of alkaloids in those plants.

Carr[4] and Reynolds refer to manurial experiments on belladonna and henbane. The results are tabulated below :—

Manures	Percentage of total alkaloids	
	Belladonna	Henbane
Unmanured . . .	0·66	0·20
Kainit	0·61	0·13
Superphosphate . .	0·46	0·11
Basic slag . . .	0·60	0·13
Farmyard manure . .	0·55	....
Sodium nitrate . .	0·52	....

It does not seem that any definite conclusions can be drawn from these experiments.

Carr[5] has published the results of experiments carried on at Dartford, Kent, during six seasons on the effect of manures on the alkaloidal content of

[1] Plant Alkaloids, p. 10.

[2] *Pflanzen microchemie*, p. 264.

[3] "Breeding for atropine." *Journ. of Heredity*, vol. III, April 1917.

[4] *Pharm. Journal*, IV, 26, 543.

[5] *Amer. J. of Pharmacy*, vol. 85, no. 11, 1913, p. 487, and *Eighth International Congress of Applied Chem.*, vol. XVII, p. 7.

belladonna. He states that the land used was naturally suited to the plants and the percentage of alkaloids obtained without manure was already high. The manures employed were farmyard manure, sodium nitrate, calcium cyanamide, basic slag, superphosphate and kainit. He concluded that the effects of fertilizers upon the percentage of alkaloid is small, tending to lower it. As regards the amount of plant harvested he states that a rich nitrogenous fertilizer will increase it severalfold if the soil is not already a rich one. Carr's experiments in this direction seem to be the most complete so far published. As will be seen later, they closely support our own conclusions in the case of opium.

Chevalier[1] has published results purporting to show that the use of nitrates with farmyard manure doubles the alkaloidal content of the dried leaves of belladonna, hyoscyamus, and stramonium, and he also concludes that potash and phosphates do not affect the alkaloidal content. His results have been referred to as conclusive[2] but the short account of his work appearing in the *Comptes rendus* would not seem to afford sufficient grounds for this opinion. The following is a reproduction of his tabulated results :—

Treatment	Total alkaloids in 100 gm. dried leaves gm.
Fields under ordinary cultivation and manuring	0·320 0·336
Fields receiving phosphoric acid and potash	0·480 0·490
Garden receiving nitrogenous manures but neither phosphoric acid nor potash .. .. (2 year old plants / Young plants ..)	0·616 0·406
Fields receiving nitrogenous manures	
(*a*) Strong soil	0·676
(*b*) Vineland-pebbly soil	0·680
(*c*) Light land with dung and nitrate added	0·756

It is apparently from the above figures that Chevalier has drawn his conclusions. Speaking from considerable experience with manurial experiments the writer would certainly not draw such general conclusions without much more supporting data. In the first place in work of this nature the error of experiment must be very large and this error does not seem to have

[1] *Comptes rendus*, 1910, 150, p. 344.

[2] *Year Book of Pharmacy*, 1910. Presidential Address to Brit. Pharm. Conf., p. 314. Also Henry, Plant Alkaloids, p. 10.

been ascertained. Moreover, all the experiments have not been carried out on the same type of land and therefore it is hardly fair to compare the results. It would also be interesting to know whether or not the same pure race of plants was used in the tests. Unless it was, this fact would also detract considerably from the value of the results.

Ransom[1] and Henderson carried out experiments with various manures on belladonna at Hitchin. The results brought no very definite conclusion and certainly do not lend much support to Chevalier's view that nitrate encourages alkaloid production. The unmanured plot produced plant with the highest alkaloid content. Rasmussen[2], in studies on the protein and nicotine content of tobacco plants during growth, found no clear relation between the fertilizers used and the nicotine contents of the resulting plants. The total nitrogen varied during growth according to the variety of the plant and the situation of the leaves tested.

Mitlacher[3] and Hayes report that manuring with stable or artificial manure does not have much influence on good soil on alkaloidal production in opium but state that on a poor soil the influence is marked.

Mukerji[4] in experiments at Pusa, India, is unable to trace any connection between manurial treatment and the nicotine content of tobacco leaves.

In short, the literature of the subject provides little satisfactory evidence that the alkaloidal content of drug-yielding plants can be modified by manuring.

The writer has carried out at Cawnpore during four seasons a careful series of experiments in order to see if any particular system of manuring of poppy has any influence on the alkaloidal content of the opium produced. The results are set out below.

1916-17 Experiments.

Two quite separate series of experiments were carried out on land which had been previously unmanured, except in the case of series II, the land used for that having received farmyard manure in 1913 at the rate of 5½ tons per acre. It was intended to use a different pure race of poppy, isolated by Mr. H. M. Leake, Economic Botanist to Government, United Provinces, for each series. Unfortunately in one series (series I) the seed used had been accidentally mixed with the seed of another race, and the resulting crop was a

[1] *International Congress of Applied Chemistry, N. Y.*, 1913. Through *Chem. and Drugg.*, 1912, 81,443.

[2] *Biochem. Ztschr.* 69 (1915), No. 5–6, pp. 461 to 466. Through *Exp. Station, Record*, Sept. 1916, p. 333.

[3] *Year Book of Pharmacy*, 1914, p. 201.

[4] *Sc. Rep. Agr. Res. Inst., Pusa*, p. 30, 1917-18.

mixture. The results in this case are therefore not so valuable as those from the other series (series II), in which no mistake occurred with the seed. Series I was carried out in field No. 29. The total area of this field was about 0·5 acre. It was divided into 16 plots, each 81′ by 13′; and all around each sub-plot was a margin of crop 2′ wide which was excluded from the experiment.

Series II was carried out on field No. 9 and in a similar manner to series I. The total area of the field was about one-third of an acre. The 16 plots each measured 45′ by 18′. The crop in each case was sown on 18th November 1916 after having been irrigated on 13th November. The seed rate used was 6 lb. per acre.

Manuring. The diagram and table show the arrangement of the plots, which was similar in each series.

Diagram showing arrangement of manurial plots.

1	16
2	15
3	14
4	13
5	12
6	11
7	10
8	9

Table showing treatment of manurial plots.

Plot No.	*Treatment*
1 and 11	.. Superphosphate and nitrate of soda.
2 and 9	.. Superphosphate, potassium sulphate and nitrate of soda.
3 and 12	.. Potassium sulphate and nitrate of soda.
4 and 10	.. Potassium sulphate and superphosphate.
5 and 15	.. Nitrate of soda.
6 and 13	.. Superphosphate.
7 and 16	.. Potassium sulphate.
8 and 14	.. Unmanured.

Each plot therefore had a duplicate in each series.

Amounts of manures and time of application.

In series I, field No. 29, superphosphate and potassium sulphate were applied at the rate of 400 lb. per acre each. The superphosphate and potassium sulphate were applied on the same day as and just before the seed. The nitrate of soda was put on in two equal dressings (at the rate of 120 lb. per acre each), the first on 2nd January 1917 and the second on 21st January 1917. The land was irrigated on the day following each application.

In series II, field No. 9, exactly the same procedure was followed, except that by an oversight the superphosphate and potassium sulphate were applied at the rate of only 320 lb. per acre.

Observations during growth.

The plots receiving potash alone showed no improvement over the unmanured ones. Wherever superphosphate had been applied the effect was very marked in a more highly developed plant but no connection could be observed between time of flowering and any particular manurial application. The effect of the nitrate was very marked indeed, and the plots to which it had been applied could be picked out within a few days owing to the dark green colour of their foliage. The nitrate plots seemed subsequently, markedly the best plots of all.

Harvesting of produce.

Opium. The capsules were lanced with a 4-bladed knife[1]. Each of the plots on field 9 received seven lancings carried out on the 8th, 11th, 14th, 17th, 20th, 23rd and 26th March, respectively. Each of the plots on field 29 received six lancings, which were carried out on the 8th, 11th, 14th, 17th, 20th and 23rd March, respectively.

The product of each lancing was kept separate. This is very necessary, since the opium of the first lancing is much the richest in morphine, and the amount of this alkaloid falls off rapidly and progressively in the opium from each of the succeeding lancings[2]. The total dry weight and the morphine content of the opium obtained at each lancing were estimated.

Straw and capsules. After lancing, the crop was left till dead ripe. The hot sun had by this time practically dried up all green parts of the plant. The total air dry weight of the plant on each plot was then recorded and also the total air dry weight of the capsules. The number of plants, and also the number of capsules on each plant, was also counted. This was done in order

[1] For details of method by which opium is extracted from the capsule in India see *Mem. Dept. Agri. India* (*Chem. Series*), vol. VI, no. 1 (pt. II).

[2] *Loc. cit.*, part III.

to see if the number of capsules borne per plant had any connection with the manure used. This is an important point, because it has been shown that the oldest capsule produces more opium, and that of a higher morphine content, than the subsequent capsules appearing on the same plant. (*See* p. 74.)

The results obtained are summarized in the Tables I to VII and illustrated diagrammatically in Chart V.

Table I.

Effect of manures on morphine content of opium.

No. of plot	Manurial treatment	Per cent. of morphine in opium dried at 100°C.						
		1st lancing	2nd lancing	3rd lancing	4th lancing	5th lancing	6th lancing	7th lancing
		Field No. 29.						
1	Super + $NaNO_3$	10·0	7·7	3·6	3·5	2·7		
2	Super + $NaNO_3$ + K_2SO_4	10·2	8·1	3·9	2·9	2·6		
3	$NaNO_3$ + K SO_4	9·5	9·1	5·0	4·1	..		
4	K_2SO_4 + super	9·7	..	4·9	3·9	3·1		
5	$NaNO_3$	9·1	7·9	4·3	5·9	2·7		
6	Superphosphate	9·3	7·1	5·8	3·8	2·6	2·3	
7	K_2SO_4	8·6	6·6	5·7	4·1	2·3		
8	No manure	7·6	8·0	3·7	4·1	2·3		
9	Super + $NaNO_3$ + K_2SO_4	9·0	4·9	4·3	4·0	1·5		
10	K_2SO_4 + super	9·6	6·5	4·4	1·4	..		
11	Super + $NaNO_3$	9·8	7·6	5·2	4·7	1·9		
12	$NaNO_3$ + K_2SO_4	9·8	7·6	4·4	4·3	2·0		
13	Superphosphate	10·3	7·9	5·3	3·0	1·2		
14	No manure	9·6	8·1	3·5	3·3	..		
15	NaNO	11·0	6·9	3·4	3·5	..		
16	K_2SO	9·7	7·3	3·8	3·7	..		
		Field No. 9.						
1	Super + $NaNO_3$	12·0	9·8	6·5	..	1·6	1·8	
2	Super + $NaNO_3$ + K_2SO_4	11·6	7·8	5·4	..	1·6	1·4	
3	$NaNO_3$ + K_2SO_4	10·2	8·7	4·8	..	2·0	..	
4	Super + K_2SO_4	9·1	8·7	4·3	..	2·0	..	
5	$NaNO_3$	10·7	8·8	6·4	4·8	3·3	2·0	
6	Superphosphate	11·3	9·2	3·6	4·0	2·5	1·2	
7	K_2SO_4	9·6	8·7	5·6	5·3	2·3	1·9	
8	No manure	8·9	8·0	5·5	..	2·5	1·6	
9	Super + K_2SO_4 + $NaNO_3$	10·8	9·9	5·0	..	3·6	2·4	
10	K_2SO_4 + super	10·3	9·6	7·1	..	3·9	1·3	
11	Super + $NaNO_3$	10·6	10·7	7·3	..	2·8	2·4	
12	$NaNO_3$ + K_2SO_4	11·4	10·0	7·9	..	3·7	2·0	
13	Superphosphate	10·3	9·6	4·4	..	1·9	2·3	
14	No manure	9·9	8·3	5·0	..	1·3	..	
15	$NaNO_3$	11·0	9·6	6·2	4·0	1·9	1·3	
16	K_2SO_4	9·7	8·8	6·0	..	1·4	1·2	

Table II.

Effect of manures on out-turn of opium.

No. of plot	Manurial treatment	Weight of opium dried at 100°C. in grm.							Total weight of opium per plot dried at 100°C. grm.	Opium dried at 100°C. lb. per acre
		1st lancing	2nd lancing	3rd lancing	4th lancing	5th lancing	6th lancing	7th lancing		
		Field No. 29.								
1	Super + $NaNO_3$	82·05	91·31	31·43	15·05	4·60	0·94	..	225·47	20·59
2	Super + $NaNO_3$ + K_2SO_4	75·49	75·06	55·43	17·59	7·82	2·00	..	233·39	21·31
3	$NaNO_3$ + K_2SO_4	42·54	65·05	49·84	16·50	3·82	1·49	..	179·24	16·36
4	Super + K_2SO_4	29·39	27·53	42·54	13·28	6·12	2·88	..	121·74	11·11
5	$NaNO_3$	18·97	67·12	52·30	25·82	8·14	1·96	..	174·33	15·92
6	Superphosphate	37·25	34·65	38·56	20·33	6·60	4·29	..	141·68	12·93
7	K_2SO_4	27·52	29·57	40·51	15·27	4·21	2·04	..	119·12	10·87
8	No manure	15·20	35·87	36·28	24·66	5·32	3·62	..	120·95	11·05
9	Super + $NaNO_3$ + K_2SO_4	67·08	63·40	37·82	15·18	4·46	2·30	..	190·24	17·37
10	Super + K_2SO_4	47·33	51·92	42·63	20·37	6·98	3·34	..	172·57	15·76
11	Super + $NaNO_3$	79·45	69·96	61·72	29·88	8·66	2·74	..	252·41	23·04
12	$NaNO_3$ + K_2SO_4	52·15	69·52	52·27	28·83	5·82	1·12	..	209·71	19·14
13	Superphosphate	46·49	43·65	37·95	15·70	4·03	3·38	..	151·20	13·80
14	No manure	46·35	55·92	40·03	13·26	2·55	0·85	..	158·96	14·52
15	$NaNO_3$	83·25	66·62	47·73	13·15	4·00	2·49	..	217·24	19·89
16	K_2SO_4	51·15	47·86	35·10	14·63	2·68	0·21	..	151·63	13·85
		Field No. 9.								
1	Super + $NaNO_3$	24·33	54·35	42·81	14·50	9·95	5·51	2·19	153·64	17·99
2	Super + $NaNO_3$ + K_2SO_4	41·25	61·91	34·93	12·30	7·85	4·69	1·86	164·79	19·30
3	$NaNO_3$ + K_2SO_4	25·60	57·19	32·48	13·50	7·64	1·98	1·60	139·99	16·39
4	Super + K_2SO_4	19·55	37·13	30·03	10·80	4·66	2·00	0·99	105·16	12·31
5	$NaNO_3$	20·17	38·12	38·60	24·85	9·50	5·46	2·17	138·87	16·27
6	Superphosphate	25·57	35·02	32·70	17·00	10·91	4·61	3·49	129·30	15·14
7	K_2SO_4	8·88	28·96	33·44	19·05	8·36	4·60	3·52	106·81	12·50
8	No manure	16·11	27·40	31·20	13·30	8·73	5·43	2·38	104·55	12·25
9	Super + $NaNO_3$ + K_2SO_4	41·58	41·50	49·40	29·00	32·22	13·34	6·82	213·86	25·04
10	Super + K_2SO_4	20·50	30·06	34·22	30·30	16·02	7·56	5·21	143·87	16·85
11	Super + $NaNO_3$	35·80	49·55	44·20	24·60	12·45	10·57	8·22	185·39	21·71
12	$NaNO_3$ + K_2SO_4	27·11	44·15	49·05	30·50	13·57	8·92	3·55	176·85	20·71
13	Superphosphate	13·98	32·13	32·13	32·37	10·71	4·63	1·89	118·41	13·87
14	No manure	18·55	32·34	23·20	14·00	5·70	1·47	0·38	95·64	11·19
15	$NaNO_3$	27·90	56·86	40·16	19·90	7·63	7·00	2·54	161·99	18·97
16	K_2SO_4	15·71	40·78	32·73	18·50	6·54	4·31	1·60	120·17	14·07

In the following table the yield of opium is expressed as the quantity yielded per 1,000 capsules.

TABLE III.

Effect of manure on out-turn of opium.

No. of plot	Manurial treatment	No. of capsules per plot	No. of capsules per plot; average of duplicates	Grm. dried opium per 1 000 capsules	Average of duplicates previous column	Weight of dried opium per 1 000 capsules unmanured plot = 100
		Field No. 29.				
8	Unmanured	4,487	4,290	27·0	32·9	100
14	,,	4,094		38·9		
7	K_2SO_4	5,015	4,762	23·8	28·7	87
16	,,	4,510		33·6		
6	Superphosphate	3,895	4,049	36·4	36·2	110
13	,,	4,203		36·0		
5	$NaNO_3$	3,857	4,227	45·2	46·2	140
15	,,	4,598		47·2		
4	K_2SO_4 + super	3,540	3,818	34·4	38·2	116
10	,,	4,086		42·1		
3	K_2SO_4 + $NaNO_3$	4,804	4,080	37·3	49·9	152
12	,,	3,357		62·5		
1	Super + $NaNO_3$	4,291	4,225	52·6	56·6	172
11	,,	4,159		60·7		
2	Super + $NaNO_3$ + K_2SO_4	4,172	3,964	56·0	53·3	162
9	,,	3,756		50·6		
		Field No. 9.				
8	Unmanured	1,897	2,145	55·1	47·5	100
14	,,	2,394		40·0		
7	K_2SO_4	2,296	2,511	46·5	45·3	96
16	,,	2,726		44·1		
6	Superphosphate	2,718	2,726	47·6	45·4	96
13	,,	2,734		43·3		
5	$NaNO_3$	2,425	2,527	57·3	59·3	125
15	,,	2,629		61·3		
4	K_2SO_4 + Super	2,578	2,671	40·8	46·4	98
10	,,	2,765		52·0		
3	K_2SO_4 + $NaNO_3$	2,375	2 703	59·0	58·6	123
12	,,	3,032		58·3		
1	Super + $NaNO_3$	2,755	2,772	55·8	62·3	131
11	,,	2,690		68·9		
2	Super + K_2SO_4 + $NaNO_3$	2,366	2,470	69·7	76·4	161
9	,,	2,574		83·1		

Table IV

Shewing relation between yield of opium per plot and per 1,000 *capsules.*

No. of plot	Manurial treatment	Total weight of opium dried at 100°C. per plot grm.	Average of duplicates previous column	Yield of opium per plot average of unmanured = 100	Grm. opium per 1,000 capsules	Average of duplicates previous column	Yield per 1,000 capsules average of unmanured =100
				Field No. 29.			
8 14	Unmanured . . .	120·9 159·9	139·9	100	27·0 38·9	32·0	100
7 16	K_2SO_4	119·1 151·6	135·3	97	23·8 33·6	28·7	87
6 13	Superphosphate . .	141·7 151·2	146·4	105	36·4 36·0	36·2	110
5 15	$NaNO_3$	174·3 217·2	195·7	140	45·2 47·2	46·2	140
4 10	K_2SO_4 + super . .	121·7 172·6	147·1	105	34·4 42·1	38·2	116
3 12	K_2SO_4 + $NaNO_3$ . .	179·2 209·9	194·5	139	37·3 62·5	49·9	152
1 11	Super + $NaNO_3$ . .	225·5 252·4	235·9	171	52·6 60·7	56·6	172
2 9	Super + K_2SO_4 + $NaNO_3$	233·4 190·2	211·8	151	56·0 50·6	53·3	162
				Field No. 9.			
8 14	Unmanured . . .	104·5 95·6	100·0	100	55·1 40·0	47·5	100
7 16	K_2SO_4	106·8 120·2	113·5	113	46·5 44·1	45·3	96
6 13	Superphosphate . .	129·3 118·4	123·8	124	47·6 43·3	45·4	96
5 15	$NaNO_3$	138·9 162·0	150·4	150	57·3 61·3	59·3	125
4 10	K_2SO_4 + super . .	105·2 143·9	124·5	124	40·8 52·0	46·4	98
3 12	K_2SO_4 + $NaNO_3$ . .	140·0 176·8	158·4	158	59·0 58·3	58·6	123
2 11	Super + $NaNO_3$ . .	153·6 185·4	169·5	169	55·8 68·9	62·3	131
2 9	Super + $NaNO_3$ + K_2SO_4	164·8 213·9	189·3	189	69·7 83·1	76·4	161

TABLE V

Shewing effect of manure on number of plants and capsules per plot.

No. of plot	Manurial treatment	No. of plants	Average of duplicates previous column	No. of plants per plot average of unmanured plots = 100	No. of capsules	Average of duplicates previous column	No. of capsules per plot average of unmanured = 100	Capsules per 100 plants
				Field No. 29.				
8 14	Unmanured	4,354 3,811	4,082	100	4,487 4,094	4,290	100	105
7 16	K_2SO_4	4,939 4,158	4,548	111	5,015 4,510	4,762	110	105
6 13	Superphosphate	3,634 3,407	3,520	86	3,895 4,203	4,049	94	115
5 15	$NaNO_3$	3,572 4,240	3,906	96	3,857 4,598	4,227	99	108
4 10	K_2SO_4 + super	3,341 3,667	3,454	85	3,540 4,096	3,818	89	110
3 12	K_2SO_4 + $NaNO_3$	4,555 2,991	3,773	92	4,808 3,357	4,080	95	108
1 11	Super + $NaNO_3$	3,953 3,685	3,819	94	4,291 4,159	4,225	99	111
2 9	Super + K_2SO_4 + $NaNO_3$	3,697 3,079	3,388	83	4,172 3,756	3,964	92	117
				Field No. 9.				
8 14	Unmanured	1,822 2,366	2,094	100	1,897 2,394	2,145	100	102
7 16	K_2SO_4	2,235 2,269	2,452	117	2,296 2,726	2,511	117	102
6 13	Superphosphate	2,606 2,607	2,606	124	2,718 2,734	2,726	127	105
5 15	$NaNO_3$	2,332 2,468	2,400	115	2,425 2,629	2,527	118	105
4 10	K_2SO_4 + Super	2,531 2,609	2,570	123	2,578 2,765	2,671	125	104
3 12	K_2SO_4 + $NaNO_3$	2,265 2,944	2,604	124	2,375 3,032	2,703	126	104
1 11	Super + $NaNO_3$	2,619 2,568	2,593	124	2,755 2,690	2,722	127	105
2 9	Super + K_2SO_4 + $NaNO_3$	2,216 2,008	2,112	101	2,366 2,574	2,470	115	117

CONTROL EXPERIMENT.

In addition a control experiment was carried out in order to determine the variations in opium yield and of morphine content of the crop from different portions of the same field, all of which had received uniform treatment. Such an experiment is of prime importance in enabling one to decide whether any different results obtained in various manurial plots are really due to a particular manurial treatment or not. For the purpose of this control experiment of

course a pure race of poppy was used—one isolated by Mr. H. M. Leake. The field contained eight plots, each measuring 34·25′ × 18·4′, and each plot was surrounded by a margin of non-experimental crop, $2\frac{1}{2}$ feet wide. Five successive lancings were made on each plot and the results are set out below :—

TABLE VI.

No. of plot	PER CENT. OF MORPHINE IN OPIUM DRIED AT 100°C. IN EACH LANCING				
	1st	2nd	3rd	4th	5th
1	11·6	10·9	11·9	7·4	6·7
2	14·3	11·5	11·5	8·5	6·7
3	13·1	10·9	10·4	6·4	5·2
4	14·3	..	..	..	..
5	12·6	10·6	8·9	4·2	4·3
6	11·5	10·0	8·3	5·9	..
7	13·1	10·5	7·6	5·0	4·8
8	11·9	11·3	8·4	5·2	..

TABLE VII.

No. of plot	WT. OF OPIUM DRIED AT 100°C. FROM EACH LANCING. GRM.					Total weight of opium per plot grm.	Lb. of opium per acre	No. of capsules per plot	Grm. of opium per 1,000 capsules
	1st	2nd	3rd	4th	5th				
1	22·22	21·41	19·83	19·17	8·86	91·49	13·96	2,371	30·6
2	9·00	18·87	27·65	31·87	11·14	98·53	15·03	2,415	40·8
3	19·88	22·35	24·35	27·67	7·32	101·57	15·50	2,294	44·3
4	15·38	20·74	22·68	34·00	8·75	101·55	15·50	2,238	45·4
5	18·49	32·71	17·55	10·72	5·32	84·79	12·94	2,478	34·2
6	12·77	23·54	13·80	10·03	3·06	63·20	9·64	2,267	27·9
7	19·22	23·25	11·88	11·25	4·04	69·64	10·63	2,075	33·5
8	15·14	23·24	14·42	13·54	2·91	69·25	10·56	2,124	32·6

Conclusions drawn from 1916-17 experiments.

A. Effect of manures on out-turn of opium.

Table II gives very definite information on this point, though the results are perhaps set out in a more convenient form in Table IV, col. 5. *Nitrate of soda* has had a very marked effect in increasing the out-turn of opium in every case. *Sulphate of potash* seems to have had no effect whatever, either alone or in combination with nitrate of soda or superphosphate. *Superphosphate* certainly seems to have had some slight effect in increasing the yield of opium. The crop in its young tages showed to the eye a marked beneficial effect in every case from the application of superphosphate, but this effect passed away as the crop grew bigger.

On field No. 9 superphosphate alone appears to have given a 24 per cent. increase in opium yield, as on both fields superphosphate and nitrate of soda gave a distinct increase over the nitrate of soda plot, and also over the plot receiving sulphate of potash plus nitrate of soda. Further Table IV shows that plots receiving superphosphate together with potash and nitrate of soda have given distinctly more opium than the plot to which only the potash and nitrate of soda were applied.

The outstanding feature, however, is the beneficial effect of the nitrate of soda.

It will be of interest to see in what way this increase of out-turn has been brought about. It might be brought about either by the manure increasing the number of capsules in a given area or by increasing the yield of opium per capsule. Table III gives a column showing the number of capsules in each manurial plot. From this it will readily be seen that the increase in yield is not attributable to the production of a larger number of capsules. Moreover let us take an instance on field 29. The unmanured plot No. 8 had 4,487 capsules. The nitrate of soda plot No. 5 had 3,857 capsules, yet the former only gave 11·05 lb. dry opium per acre as against 15·92 lb. yielded by the latter. It would seem obvious that the increase in yield brought about by nitrate of soda was due to an increase in yield of the individual capsules.

Table IV shows the relation between the yield of opium per plot and per 1,000 capsules in each plot. A comparison between cols. 5 and 8 of that table is interesting, for the relation between the yield per plot, and yield per 1,000 capsules in each plot, is distinct and especially so in field 29.

In the field one could not help noticing how much bigger the capsules on the nitrate of soda plots were than those on plots receiving no nitrate of soda

B. Effect of manure on morphine content of the opium.

In considering this effect one should only take into consideration the morphine content of the first lancings,[1] since at the second lancing the opium obtained is a mixture of the produce of heads some of which have been lanced twice and others only once. The morphine content of the opium of the later lancings has been given as a matter of interest.

A study of Table I shows that on field 29 the morphine content of the opium of the first lancings has varied from 7·6 to 11·0 and in field 9 from 8·9 to 12·0. Before considering these variations it is of importance to refer to Table VI which gives the morphine content of the opium grown on 8 plots of an unmanured field. It will be seen that the morphine content varied from 11·5 to 14·3 per cent. on different parts of the field. This is about the range of the variation in morphine content of opium of the first lancing which we have since found in experiments in which we have grown five or six acres of the same pure race of poppy. It is almost as great as the range of variation in morphine content on the various plots of fields 9 and 29. Hence the effect of manure on the morphine content cannot be very marked.

The following table will help in considering any possible manurial effect :—

TABLE VIII.

No. of plot	Manurial treatment	Morphine content of opium of 1st lancing	Average of duplicates previous column
		Field No. 29.	
8	No manure	7·6	8·6
14	,,	9·6	
7	Potassium sulphate	8·6	9·1
16	,,	9·7	
6	Superphosphate	9·3	9·8
13	,,	10·3	
5	Nitrate of soda	9·1	10·0
15	,,	11·0	
4	K_2SO_4 + superphosphate	9·7	9·6
10	,,	9·6	
3	K_2SO_4 + $NaNO_3$	9·5	9·6
12	,,	9·8	
1	Super + $NaNO_3$	10·0	9·8
11	,,		
2	Super + K_2SO_4 + $NaNO_3$	10·2	9·6
9	,,	9·0	

[1] The morphine content rapidly diminishes in the opium from each successive lancing of a given capsule (see *Mem. Dept. Agri. India* (*Chem. Series*), vol, VI, no. 1 (pt. III).

TABLE VIII.—*concld.*

No. of plot	Manurial treatment	Morphine content of opium of 1st lancing	Average of duplicates previous column
		Field No. 9.	
8	No manure	8·9	9·4
14	„	9·9	
7	Potassium sulphate	9·6	9·6
16	„	9·6	
6	Superphosphate	11·3	10·8
13	„	10·3	
5	Nitrate of soda	10·7	10·8
15	„	11·0	
4	K_2SO_4 + super	9·1	9·7
10	„	10·3	
3	K_2SO_4 + $NaNO_3$	10·2	10·8
12	„	11·4	
1	Super + $NaNO_3$	12·0	11·3
11	„	10·6	
2	Super + K_2SO_4 + $NaNO_3$ . . .	11·6	11·2
9	„	10·9	

It would seem that, if the morphine content has been affected by any particular system of manuring, the effect is very slight. The effect is not as great as the experimental error (already set out) to be expected in such work. It so happens that, in both fields 9 and 29, the average of the morphine content of the opium from each pair of unmanured plots is the lowest of any of the plots, yet in field 29, unmanured plot No. 14 has given 9·6 per cent. morphine in its opium, which figure is higher than that from plots Nos. 3, 5, and 9 receiving nitrate of soda. Similarly, in field 9 one of the unmanured plots has produced opium of quite a high morphine content. It must be admitted, however, that in both fields there is some slight indication that nitrate of soda has slightly raised the morphine content of the opium. This increase is, however, much within the limits of the experimental error. It is also practically within the amount of the experimental error allowed for the method of analysis employed (*B. P.* 1914), *viz.*, 0·5 per cent. morphine either way.

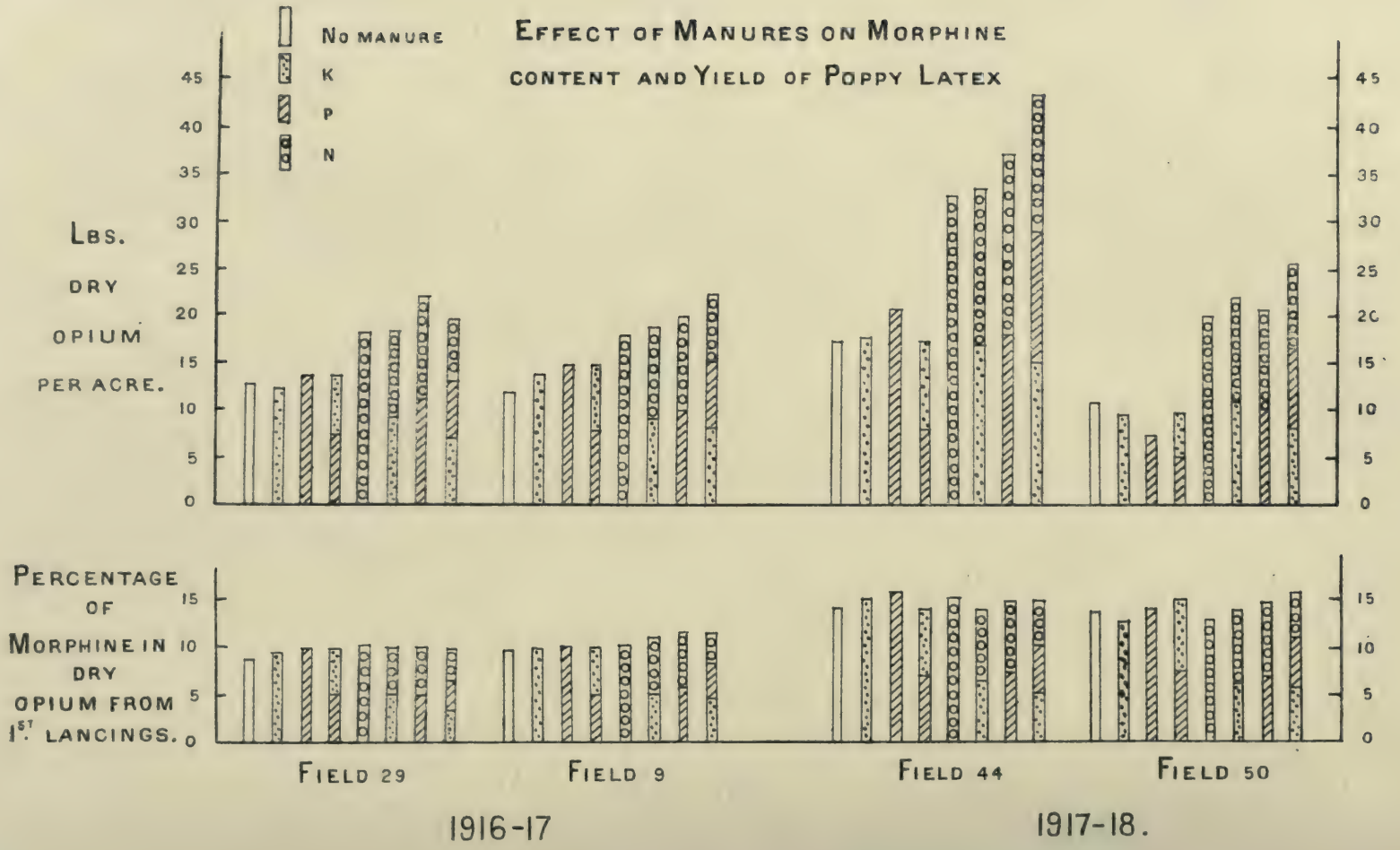

No manure
K
P
N
Effect of Manures on Morphine
content and Yield of Poppy Latex
Lbs.
dry
opium
per acre.
0
5
10
15
20
25
30
35
40
45
Percentage
of
Morphine in
dry
opium from
1st lancings.
0
5
10
15
Field 29
Field 9
Field 44
Field 50
1916-17
1917-18.

CHART V.

The striking fact however is that nitrate of soda has a truly enormous effect on the yield of opium, yet the effect on the morphine content of that opium is almost inappreciable. This is well emphasized in the diagrams. (Chart V.)

It will be of interest to remark here that the unmanured plots produced undoubtedly ill-nourished plants.

1917-18 Experiments.

These experiments were much on the lines of those of the previous year. Two adjoining fields, each of ½ acre area, were used for the experiment. 10 plots were laid out in each field, measuring 58′ × 30,′ or almost exactly 1/40th of an acre each. Around each plot was left a margin of crop 2 feet wide which was excluded from the experiment. In this year were also included plots receiving cattle manure and castor cake. Seed of a pure race of poppy was sown over the whole area, but it was not the same as had been used for the manurial experiment in the previous season.

The crop was sown on the 31st October 1917. The land had not been irrigated owing to an opportune fall of rain some few days previously. The seed rate was 6 lb. per acre.

Manuring. The diagram shows the arrangement of the plots which was exactly similar in each field.

5	6
4	7
3	8
2	9
1	10

Plot 1 received cattle manure
„ 2 „ superphosphate, potassium sulphate and nitrate of soda.
„ 3 „ superphosphate and nitrate of soda.
„ 4 „ sulphate of potash and nitrate of soda.
„ 5 „ sulphate of potash and superphosphate.
„ 6 „ nitrate of soda.
„ 7 „ superphosphate.
„ 8 „ sulphate of potash.
„ 9 was unmanured.
„ 10 received castor cake.

Amounts of manures and time of application. The dressings this year were even larger than in the previous year. It must be remembered that large dressings were deliberately put on as the main object was to see if manuring could modify the alkaloidal content of the opium produced by the plant.

Superphosphate was	applied at the rate of	8 mds.	or 658 lb.	per	acre.
Sulphate of potash	,, ,,	8 mds.	or 658 lb.	,,	,,
Nitrate of soda	,, ,,	4 mds.	or 329 lb.	,,	,,
Castor cake	,, ,,	20 mds.	or 1,646 lb.	,,	,,
Cattle manure	,, ,,	300 mds.	or 11·11 tons	,,	,,

The superphosphate and sulphate of potash were sown on the same day as and just before the seed. The nitrate of soda was put on in two equal dressings, the first on the 3rd January 1918, and the second on the 22nd January 1918. The land was irrigated immediately after each application.

Observations during growth. These were practically the same as during the previous season. Potash seemed to have only a slight effect. The effect of superphosphate was distinctly marked in the production of a larger plant. This improvement was noticed when applied alone and with reference to unmanured plots, and also when applied with nitrate of soda and with reference to the plots receiving nitrate of soda alone. The effect of nitrate of soda was again very marked showing up within two to three days of its application. The nitrate of soda plots quickly assumed and retained a dark green foliage and the plants developed very rapidly. Plots No. 10 receiving castor cake were very similar to the plots No. 2 receiving the nitrate, superphosphate, and potassium sulphate.

No connection could be observed between time of flowering and application of any particular manure.

Harvesting of opium. The fields were not all ready for harvesting at the same time. Field 44 was harvested in the usual Indian way.[1] The knife used had 4 parallel blades.

In field 50 the capsules at each lancing received three parallel vertical cuts with the knife, with the idea of increasing the yield of opium.

On both fields the number of capsules lanced at the first lancing in each plot was recorded, so that data could be obtained of the yield of opium per

[1] Annett, Sen and Singh. *Mem, Dept. Agri. India, Chem. Ser.*, vol. VI, no. 1 (part II).

capsule at the first lancing. This could not be done at every lancing, owing to the mass of work involved in such a proceeding.

The opium was allowed to dry in the laboratory at the ordinary temperature of the room, *viz.*, about 100 °F., by being spread out in a thin layer. When dry enough, it was torn into small pieces and these were again spread out to dry until the whole sample could be powdered and sieved. The samples then contained from 92 to 95 per cent. dry matter. The total dry matter and morphine content of each sample were then estimated. For the morphine estimation the air-dry powdered samples were taken. The loss of weight on drying the sample in the oven was estimated in a separate 2 gm. portion.

The codeine and narcotine content of the first lancings on field 44 were also determined.

Methods of analysis.

Morphine was estimated by the method of the *British Pharmacopœia*, 1914.

Codeine was estimated by a new method we have devised.[1]

Narcotine was estimated in the ether extract of the dried opium by extracting the ether extract with acid, addition of ammonia to the acid extract and re-extracting the narcotine with ether.

Straw, capsules, and seed. After harvesting the opium, the crop was left until dead ripe as in the previous year. The hot sun had by then dried up all green parts of the plant. The total air-dry weight of the above ground portions of the plants was then recorded, and also the total air-dry weight of the capsules. The number of plants and of capsules in each plot was also recorded in order to determine if the number of capsules borne per plant had any connection with the manure used. Finally the seed was separated from the capsules and the weight of seed on each sub-plot was determined.

The attached tables give the results of the experiments. Chart V expresses the results diagrammatically.

[1]The *Analyst*, XLV, 1920, p. 321.

TABLE IX.

Effect of manure on morphine, codeine and narcotine content of opium.

No. of plot	Manurial treatment	PER CENT. OF MORPHINE IN OPIUM DRIED AT 100°C. OF EACH SUCCESSIVE LANCING						Percentage of codeine in opium of 1st lancing	Percentage of narcotine in opium of 1st lancing	Total morphine narcotine and codeine in 1st lancing
		1st	2nd	3rd	4th	5th	6th			
		Field 44. Country lancing.								
9	Unmanured	14·1	12·4	9·4	6·3	3·0	2·3	2·14	4·63	18·8
8	Sulphate of potash	14·9	11·5	8·6	7·3	4·5	1·4	2·20	4·36	21·5
7	Superphosphate	15·8	12·0	8·0	6·3	4·2	1·2	1·48	5·00	22·3
6	Nitrate of soda	15·0	11·1	8·7	6·4	4·0	..	2·18	5·06	22·2
5	K_2SO_4 + super	13·8	12·1	8·7	5·9	3·6	..	1·72	3·34	18·7
4	K_2SO_4 + $NaNO_3$	13·8	11·4	7·9	6·3	4·8	2·1	1·81	7·74	22·8
3	Superphosphate + nitrate of soda	14·9	13·0	8·1	6·1	3·3	2·5	2·21	5·70	22·9
2	Superphosphate + K_2SO_4 + $NaNO_3$	14·7	11·7	9·5	5·4	2·3	1·6	2·19	4·92	21·8
1	Cattle dung	14·7	11·8	8·8	6·2	3·7	2·0	2·91	4·79	22·4
10	Castor cake	14·5	12·5	10·3	5·1	4·1	2·6	2·33	3·57	20·4
		Field 50. Treble lancing.								
9	Unmanured	13·4	11·2	9·1	..	..	..	Not estimated		
8	Sulphate of potash	12·6	9·4	5·6	..	..	..	,,	,,	
7	Superphosphate	13·9	10·3	9·0	..	..	..	,,	,,	
6	Nitrate of soda	12·5	10·6	10·2	..	..	..	,,	,,	
5	K_2SO_4 + super	14·8	12·1	8·3	..	..	..	,,	,,	
4	K_2SO_4 + $NaNO_3$	13·7	11·3	9·4	..	..	..	,,	,,	
3	Super + $NaNO_3$	14·7	10·4	11·1	..	..	..	,,	,,	
2	Super + K_2SO_4 + $NaNO_3$	15·7	13·4	9·8	8·4	6·2	..	,,	,,	
1	Cattle dung	14·7	13·3	9·9	7·8	8·4	..	,,	,,	
10	Castor cake	16·7	10·9	9·5	6·6	8·0	..	,,	,,	

Note. The marginal areas around the plots were also lanced for opium. The plants there had, of course, received no manure and being close up to the edges of the field were mostly small and stunted largely owing to edges of the field being badly cultivated. Two samples of opium, 1st lancings only, collected from around and between the plots of fields 44 and 50, were found to contain 14·5 and 13·2 per cent. morphine respectively.

Table X.

Effect of manures on out-turn of opium.

No. of plot	Manurial treatment	Weight of opium in grm. at each successive lancing dried at 100°C.							Total weight of dry opium per plot grm.	Lb. of dried opium per acre	Yield of dry opium unmanured plot = 100
		1st	2nd	3rd	4th	5th	6th	7th			
		Field No. 44. Country lancing.									
9	Unmanured . .	67·7	50·4	32·7	24·6	12·0	6·4	..	193·8	17·11	100
8	K_2SO_4 . . .	72·1	67·8	35·7	12·5	9·0	2·2	0·5	199·8	17·64	103
7	Superphosphate .	70·7	83·1	52·7	10·7	11·6	3·6	0·7	233·1	20·59	120
6	$NaNO_3$ . . .	169·7	34·9	39·1	12·4	6·8	1·7	0·4	365·0	32·22	188
5	K_2SO_4 + super .	78·5	66·2	24·1	13·8	7·4	1·6	0·6	192·2	16·97	99
4	K_2SO_4 + $NaNO_3$.	132·9	126·3	68·0	29·7	11·8	2·7	0·4	371·8	32·83	192
3	Super + $NaNO_3$.	164·5	124·1	89·5	33·95	0·2	3·2	..	420·4	37·11	217
2	Super + K_2SO_4 + $NaNO_3$ . . .	180·4	157·0	53·9	54·43	0·31	3·4	..	489·4	43·22	253
1	Cattle dung . .	91·4	85·1	24·7	18·81	0·5	4·0	..	234·5	20·71	121
10	Castor cake . .	123·7	88·9	40·3	22·2	9·8	3·2	..	288·1	25·4	149
		Field No. 50. Treble lancing.									
9	Unmanured . .	79·6	34·7	5·1	..	..	..	..	119·4	10·54	100
8	K_2SO_4 . . .	88·0	17·6	3·5	..	..	..	..	109·1	9·63	91
7	Superphosphate .	53·4	20·3	6·0	..	..	..	..	79·7	7·04	67
6	$NaNO_3$ . . .	182·2	34·7	8·8	..	..	..	..	225·7	19·93	189
5	K_2SO_4 + super .	75·1	29·4	5·3	..	..	..	..	109·8	9·70	92
4	K_2SO_4 + $NaNO_3$.	188·9	45·2	13·3	..	..	..	..	247·4	21·85	207
3	Super + $NaNO_3$.	146·4	74·8	9·1	..	..	..	..	230·3	20·33	193
2	Super + K_2SO_4 + $NaNO_3$ . . .	122·7	91·5	68·4	2·5	2·2	..	..	287·3	25·36	241
1	Cattle dung . .	93·9	37·0	32·5	2·2	9·1	..	..	174·7	15·43	146
10	Castor cake . .	198·5	49·1	44·3	2·2	4·2	..	..	298·3	26·60	250

TABLE XI.

Shewing effect of manures on out-turn of opium per 1,000 capsules.

No. of plot	Manurial treatment	OPIUM OF 1ST LANCING				TOTAL YIELD			
		No. of capsules per plot lanced at 1st lancing	Yield of dry opium grm.	Yield of dry opium per 1,000 capsules grm.	Yield of unmanured plot = 100	No. of capsules per plot	Yield of dry opium grm.	Yield of dry opium per 1,000 capsules grm.	Yield of unmanured plot = 100
		Field 44. Country lancing.							
9	Unmanured	1,910	67·7	35·4	100	5,755	193·8	33·7	100
8	K_2SO_4	2,698	72·1	26·7	75	4,645	199·9	43·0	128
7	Superphosphate	2,241	70·7	31·5	89	5,245	233·1	44·4	132
6	$NaNO_3$	4,044	169·7	42·0	118	5,903	365·0	61·9	184
5	K_2SO_4 + super	3,180	78·5	24·7	70	5,348	192·3	36·0	107
4	K_2SO_4 + $NaNO_3$	3,276	132·0	40·6	114	6,470	371·8	57·5	171
3	Super + $NaNO_3$	3,530	164·5	46·6	131	5,909	420·4	71·1	211
2	Super + K_2SO_4 + $NaNO_3$	3,240	180·4	55·7	157	5,214	489·4	93·9	279
1	Cattle dung	2,736	91·4	33·4	94	5,232	234·6	44·8	133
10	Castor cake	3,212	123·7	38·5	109	5,752	288·2	70·0	208
		Field 50. Treble lancing.							
9	Unmanured	2,732	79·6	29·1	100	6,134	119·4	19·5	100
8	K_2SO_4	3,812	88·0	23·1	79	6,770	107·1	16·1	83
7	Superphosphate	2,910	53·4	18·3	63	7,285	79·7	10·9	56
6	$NaNO_3$	4,090	182·2	44·3	153	7,673	225·7	29·4	151
5	K_2SO_4 + Super	2,545	75·1	29·5	101	8,864	109·8	12·4	64
4	K_2SO_4 + $NaNO_3$	4,044	188·9	46·7	160	5,967	247·4	41·5	213
3	Super + $NaNO_3$	3,220	146·4	45·4	156	6,813	230·3	33·8	174
2	Super + K_2SO_4 + $NaNO_3$	2,343	122·7	52·4	160	7,025	287·3	40·9	210
1	Cattle dung	1,941	93·9	48·4	166	5,570	174·7	31·3	161
10	Castor cake	3,470	198·5	57·2	198	6,225	298·3	47·9	246

One great difference will be observed between fields 44 and 50 in the above tables. The figures in column 6 differ very considerably from those in column 10, in the case of field 44, whereas in field 50 they fairly well correspond in most cases. This is because in No. 50 the main bulk of the yield of opium was obtained at the first lancing. It will be remembered that the capsules in this plot all received three incisions at each lancing, and in this method the yield of opium rapidly falls off at each subsequent lancing. In field 44, however, the ordinary country lancing method of making one incision with a 4-bladed knife was used, and it is our experience that the individual capsules frequently give more opium by this method at the second lancing than at the first. For this reason the yield of opium of the individual capsule at the first lancing is not a fair indication of the total yield of opium to be expected from these same capsules on each manurial plot.

Table XII.

Shewing relation between yield of opium per 1,000 *capsules and per plot.*

No. of plot	Manurial treatment	Total weight of opium dried at 100°C. per plot grm.	Yield of opium per plot unmanured = 100	Yield of opium per 1,000 capsules grm.	Yield of opium per 1,000 capsules unmanured = 100
		Field No. 44.			
9	Unmanured	193·8	100	33·7	106
8	K_2SO_4	199·8	103	43·0	128
7	Superphosphate	233·1	120	44·4	132
6	$NaNO_3$	365·0	185	61·9	184
5	Super + K_2SO_4	192·3	99	36·0	107
4	K_2SO_4 + $NaNO_3$	371·8	192	57·5	171
3	Super + $NaNO_3$	420·4	217	71·1	211
2	Super + K_2SO_4 + $NaNO_3$ . .	489·4	253	93·9	279
1	Cattle dung	234·6	121	44·8	133
10	Castor cake	288·2	149	70·0	208
		Field No. 50.			
9	Unmanured	119·4	100	19·5	100
8	K_2SO_4	109·1	91	16·1	83
7	Superphosphate	79·7	67	10·9	56
6	$NaNO_3$	285·7	189	29·4	151
5	Super + K_2SO	109·8	92	12·4	64
4	K_2SO_4 + $NaNO_3$ . . .	247·4	207	41·5	213
3	Super + $NaNO_3$	230·3	193	33·8	174
2	Super + K_2SO_4 + $NaNO_3$ . .	287·3	241	40·9	210
1	Cattle dung	174·7	146	31·3	161
10	Castor cake	298·3	250	47·9	246

Table XIII.

Shewing effect of manure on weights of plants and capsules per plot.

Plot No.	Manurial treatment	Weight of plants with capsules per plot lb.	Yield of opium per plot. unmanured plot = 100	Weight of capsules per plot lb.	Wt. of capsules per plot unmanured = 100
			Field No. 44.		
9	Unmanured	55·6	100	29·9	100
8	K_2SO_4	63·9	115	30·9	103
7	Superphosphate	74·2	133	36·0	120
6	$NaNO_3$	96·8	174	49·2	164
5	K_2SO_4 + super	68·0	122	37·1	123
4	K_2SO_4 + $NaNO_3$	92·7	167	45·8	153
3	Super + $NaNO_3$	118·2	213	56·6	186
2	Super + K_2SO_4 + $NaNO_3$ . .	121·5	218	54·1	180
1	Cattle dung	74·2	133	36·0	120
10	Castor cake	93·7	168	42·2	140
			Field No. 50.		
9	Unmanured	59·7	100	31·4	100
8	K_2SO_4	62·3	104	32·9	105
7	Superphosphate	63·9	107	30·9	98
6	$NaNO_3$	96·8	162	48·4	154
5	K_2SO_4 + super	64·9	109	30·9	98
4	K_2SO_4 + $NaNO_3$	99·4	166	49·4	157
3	Super + $NaNO_3$	121·0	203	55·1	175
2	Super + K_2SO_4 + $NaNO_3$ . .	117·4	197	52·5	167
1	Cattle dung	64·9	109	34·0	108
10	Castor cake	112·8	189	53·6	170

TABLE XIV.

Effect of manures on number of plants and capsules per plot.

No. of plot	Manurial treatment	Number of plants	No. of plants per plot unmanured = 100	No. of capsules	No. of capsules per plot unmanured = 100	No. of capsules per 100 plants
		Field No. 44.				
9	Unmanured	5,502	100	5,755	100	105
8	K_2SO_4	4,413	80	4,645	81	105
7	Superphosphate	4,700	85	5,245	91	112
6	$NaNO_3$	5,716	104	5,903	103	103
5	K_2SO_4 + super	4,994	91	5,348	93	107
4	K_2SO_4 + $NaNO_3$	6,279	114	6,470	112	103
3	Super + $NaNO_3$	5,517	100	5,909	103	107
2	Super + K_2SO_4 + $NaNO_3$	*	..	5,214	91	..
1	Cattle dung	5,142	93	5,232	91	102
10	Castor cake	5,361	97	5,752	100	107
		Field No. 50.				
9	Unmanured	6,035	100	6,134	100	102
8	K_2SO_4	6,571	109	6,770	110	103
7	Superphosphate	7,192	119	7,285	119	101
6	$NaNO_3$	7,571	125	7,673	125	101
5	K_2SO_4 + super	7,928	131	8,864	144	112
4	K_2SO_4 + $NaNO_3$	5,830	97	5,967	99	102
3	Super + $NaNO_3$	6,506	103	6,613	111	105
2	Super + K_2SO_4 + $NaNO_3$	6,617	110	7,025	114	106
1	Cattle dung	5,146	85	5,570	91	108
10	Castor cake	5,778	96	6,225	101	108

* Not available.

TABLE XV.

Relation between yield of opium, capsules and seed per acre.

Plot No.	Manurial treatment	Out-turn of opium dried at 100°C.		Out-turn of capsules		Out-turn of seed.	
		lb. per acre	Unmanured plot = 100	lb. per acre	Unmanured plot = 100	lb. per acre	Unmanured plot = 100
		Field No. 44. Country lancing.					
9	Unmanured	17·11	100	1,196	100	555·6	100
8	K_2SO_4	17·64	103	1,236	103	632·8	114
7	Superphosphate	20·59	120	1,440	120	689·6	124
6	$NaNO_3$	32·23	188	1,968	164	982·8	177
5	K_2SO_4 + super	16·97	99	1,484	123	957·2	172
4	K_2SO_4 + $NaNO_3$	32·83	192	1,832	153	895·6	161
3	Super + $NaNO_3$	37·11	217	2,264	186	1126·4	203
2	Super + K_2SO_4 + $NaNO_3$	43·22	253	2,164	180	1069·6	203
1	Cattle dung	20·71	121	1,440	120	704·4	127
10	Castor cake	25·45	149	1,688	140	843·6	152
		Field No. 50. Triple lancing.					
9	Unmanured	10·54	100	1,256	100	617·2	100
8	K_2SO_4	9·63	91	1,316	105	637·6	103
7	Superphosphate	7·04	67	1,236	98	580·8	94
6	$NaNO_3$	19·93	189	1,936	154	869·2	141
5	K_2SO_4 + super	9·70	92	1,236	98	586·8	95
4	K_2SO_4 + $NaNO_3$	21·85	207	1,976	157	957·2	155
3	Super + $NaNO_3$	20·33	193	2,204	175	1131·6	183
2	Super + K_2SO_4 + $NaNO_3$	25·36	241	2,100	167	1049·2	170
1	Cattle dung	15·43	146	1,360	108	637·6	103
10	Castor cake	26·60	250	2,144	170	1039·2	169

Conclusions drawn from 1917-18 experiments.

A. Effect of manures on out-turn of opium.

Tables X and XI deal with this effect and Chart V sets out the results diagrammatically. The previous year's conclusions were amply confirmed by the experiments of 1917-18. Nitrate of soda has again had a very marked effect in increasing the out-turn of opium in every case in which it was applied. The amount used seems to have almost doubled the yield of opium.

Sulphate of potash again has had no effect when applied alone, and practically none when applied with nitrate of soda. When applied with superphosphate and nitrate of soda together it seems, however, to have had an effect, for the yields on plot 2 in each field are greater than on plot 4. Plot 2 received all three artificial manures, while plot 4 received superphosphate and nitrate of soda, but no potash.

Superphosphate, applied alone, appears to have had a slight beneficial effect on field 44 but none on field 50. Applied in conjunction with potash, it seems to have had no effect on either field. But when applied together with potash and nitrate of soda (plot 2 on each field) it has given a distinct increase in yield on both fields over the plots receiving potash and nitrate of soda.

The experiments again show that the increased out-turn, produced by nitrate of soda, is due to an increase of yield of the individual capsules. Thus Table XIV shows the number of capsules on each of the differently manured plots. It will be seen that the differences are not great. Moreover, Table XII shows that a very close relation exists between the yield of opium per plot and per 1,000 capsules in each plot.

Table XV shows also that there is again a fairly general relation between the yield of opium per plot and the total weight of capsules in each plot. Since manuring does not seem to affect the number of capsules per plot (*see* Table XIV), the yield of opium for a given pure race of poppy would appear to be proportional to the size and weight of the capsule.

B. Effect of manures on out-turn of seed.

This is shown in Table XV. Manures seem to have had the same effect on the seed out-turn as they had on the out-turn of opium. There is but one exception, that on plot 5 of field 44 receiving potash and superphosphate. This plot has given a very high yield of seed. With this exception Table XV shows that the yield of seed is almost exactly proportional to the yield of opium and fairly well proportional to the total weight of the capsules on the

various plots. The relation is not so good in field 50 as in field 44, probably owing to the fact that the method of lancing used on field 50 caused capsules to yield less opium than they would have yielded by the ordinary method of lancing.

C. Effect of manures on the alkaloid content of the opium.

1. *Morphine.* The results are an ample confirmation of our conclusions from last year's result and are well illustrated diagrammatically in Chart V. That is, the percentage of morphine in the opium has not been modified to an appreciable extent by any system of manuring. This is well seen in Table IX. On referring to page 99, it will be seen that in a control experiment it was found that the morphine content of opium produced in eight different plots of the same field uniformly treated varied from 11·5 to 14·3.

A control experiment was also carried out in the season 1918-19.

The opium collected from the first lancings of the eight plots into which the control field was divided gave the following percentage of morphine :— 12·8, 12·1, 12·9, 12·2, 11·8, 12·0, 12·6, and 12·6.

The results were therefore much more uniform than those of the previous year's control experiment. The range of variation in morphine percentage of the opium produced at the first lancing on the various manurial plots of field 44 was very small, *viz.*, 14·1 to 15·8. On field 50, due no doubt to the different method of lancing adopted, the range of variation was greater, *viz.*, 12·6 to 16·7.

There is, moreover, not much variation in the various plots of the morphine content of the opium of the second, third, and subsequent lancings. One big difference will be observed in the table between fields 50 and 44. The morphine content of the opium from the fourth and fifth lancings of the former field are considerably higher than those on plot 44. This is explained by the fact that on field 50 treble lancing was employed as previously stated. This method of lancing soon dries up the capsules, say after the second or at latest third lancing, and many capsules yield no further latex by this system even at the second lancing. Therefore in field 50, at the fourth and subsequent lancings, as compared with field 44, we shall have a higher proportion of heads being lanced for the first time. It has been shown that heads lanced for the first time produce opium with the highest percentage of morphine, and hence in the fourth and fifth lancings from field 50 one would expect the opium to contain more morphine than the opium from the fourth and fifth lancings of field 44.

Finally, nitrate of soda has again had an enormous effect on the out-turn of opium, but, at the same time, the percentage of morphine in that opium seems to have undergone no change at all. This is well illustrated in Chart V.

2. *Codeine.* The codeine content of the opium from the various plots has varied from 1·48 to 2·91. This latter figure was obtained on the plot receiving cattle dung. Omitting this figure and the figure from the castor cake plot the range of variation on the remaining plots was from 1·48 to 2·29. The error in the method of analysis is probably not more than 0·10 per cent. The codeine content on plots 2, 3, 6, 8 and 9 are practically identical, and there seems to be no connection between any particular manurial application and the codeine content of the opium produced.

3. *Narcotine.* The narcotine content has varied from 2·55 to 7·16 per cent. The unmanured plot has produced opium of the lowest narcotine content. The variations in the narcotine content do not however appear to have any relation to any particular manurial application.

1919-20 Experiments.

In the seasons 1918-19 and 1919-20 the experiment was limited to determining the effect of nitrogen in increasing amounts applied in the form of $NaNO_3$ and also in the form of poppy cake and castor cake. The 1918-19 results were unsatisfactory since the crop was very uneven, but in any case the results are not available owing to damage caused to the samples by a fire which broke out in the laboratory.

In the season 1919-20 the field used was half an acre in area and was divided into 16 equal plots: the whole ½ acre was sown with seed of the same pure race of poppy and a margin of non-experimental plot was left all round each plot. Opium was however collected from the capsules in these marginal areas and analyses of the samples so collected provided a check on the results from the manurial plots and also acted as a control on the possibility of creepage effects of manures.

The amounts of manure applied are shown in the tables. The nitrate of soda was in each case put on in two dressings, the first on 21-12-19 and the second on 13-1-20.

Harvesting of produce.

Opium. When lancing commenced, as many terminal capsules in each plot as were ready were selected and labelled and counted. These heads received four successive lancings. In this way we were able to determine the yield per 1,000 heads at each successive lancing in each plot, and also we were certain that the produce of the second lancing did not contain opium from heads lanced for the first time and so on. Later on more terminal heads came to maturity and on some of the plots these were lanced. No subsequent ancing was carried out in these however. Thus a duplicate set of data was

obtained for some of the plots. The remaining capsules on the plot were not lanced since we were concerned with the yield of latex per plant rather than with the total produce per plot.

Straw, capsules, and seed. After harvesting the opium the plants were allowed to dry in the hot sun on the plots and were then cut and removed to the threshing yard. Here they were allowed to dry further in the sun and the total produce of each plot was weighed. The total weight of capsules and of seed per plot were also determined and also from each plot the weight of 1,000 terminal capsules and of the resulting seed.

The total number of plants and of capsules per plot were also counted in order to see if the varying amount of manure affected the number of capsules per plot. As in 1916-17 this was found not to be the case and therefore the figures will not be reproduced here. The following tables set out our results.

TABLE XVI.

Effect of nitrogenous manures on morphine and codeine content of opium.

Treatment per acre	PERCENTAGE OF MORPHINE IN DRY MATTER OF OPIUM					Percentage of codeine in dry matter of opium of first lancing
	No. of lancing				Second crop of capsules first lancing	
	1	2	3	4		
Unmanured	14·4	9·4	4·3	3·6	14·4	3·70
"	14·4	10·9	6·5	4·5	..	3·46
80 lb. $NaNO_3$	15·9	11·3	6·5	4·4	..	3·89
"	14·6	10·2	6·7	4·7	14·6	3·24
160 lb. $NaNO_3$	15·9	10·5	6·4	3·8	..	3·96
"	15·0	11·0	6·8	4·4	..	3·77
320 lb. $NaNO_3$	15·0	9·9	4·8	3·8	15·0	3·50
"	15·9	12·1	7·1	5·0	14·9	3·41
480 lb. $NaNO_3$	15·8	11·2	6·4	3·8	14·8	3·74
"	16·1	10·3	6·8	4·4	..	3·26
640 lb. $NaNO_3$	16·6	11·1	5·8	3·2	15·3	3·84
"	16·4	10·1	5·7	3·8	..	3·48
1,600 lb. poppy cake supplying N = 530 lb. $NaNO_3$	16·7	11·6	6·0	5·3	15·6	3·52
"	15·7	10·9	6·7	4·1	..	3·81
1,600 lb. castor cake supplying N = 580 lb. $NaNO_3$	17·5	11·9	7·5	4·2	..	3·95
"	17·1	11·9	7·3	5·0	..	4·27

Note. On each plot the opium was collected in duplicate samples which were analysed separately. The average of these two samples only is given, since they agreed very closely in practically every case.

In addition, eight samples of opium of the first lancings only, harvested from the margins between the plots, gave the following figures for morphine content, 14·8, 16·0, 14·4, 14·9, 14·8, 15·0, 15·3 and 14·8, with an average of 15·0, which fairly well agrees with the average figures obtained for the unmanured plots. Six of these samples from the marginal areas were also examined for codeine content and gave the following figures, 3·57, 3·51, 3·83, 4·20, 4·01 and 4·70.

TABLE XVII.

Effect of manures on yield of opium per 1,000 *capsules.*

Treatment per acre	GM. OPIUM RECKONED AS DRY MATTER PER 1,000 CAPSULES					UNMANURED PLOT = 100	
	No. of lancing					1st lancing yield	Total yield of all lancings
	1	2	3	4	Total		
Unmanured . . .	35·2	26·4	7·6	2·2	71·4	100	100
80 lb. $NaNO_3$ . .	37·3	28·5	15·3	9·2	90·3	106	127
160 ,, . .	43·6	34·7	14·4	8·5	101·2	124	142
320 ,, . .	39·9	21·7	9·0	2·9	73·5	113	103
480 ,, . .	50·6	32·0	8·1	2·4	93·1	144	130
640 ,, . .	55·7	34·1	6·0	5·3	101·1	158	142
1,600 lb. poppy cake containing N = 530 lb. $NaNO_3$ . . .	53·8	44·5	13·3	6·9	118·5	153	166
1,600 lb. castor cake containing N = 580 lb. $NaNO_3$ . . .	51·6	49·5	20·3	16·4	137·8	146	193

Note. These figures are only approximate. Unfortunately portions of some of the samples were stolen from the laboratory and before the actual moisture content of the samples had been determined. Luckily, however, the field weights of the samples in the moist condition were available and we are convinced that all the weights are within 5 per cent. of the truth.

TABLE XVIII.

Relation between weights of plants, capsules, seed and opium. Unmanured plot 100.

Treatment per acre	Total plant produce per plot	Weight of 1,000 complete plants (sun-dried)	Weight of 1,000 terminal capsules (sun-dried)	Weight of seed from 1,000 terminal capsules.	YIELD OF OPIUM (DRY MATTER) PER 1,000 CAPSULES	
					At 1st lancing	Total of all lancings
Unmanured	100	100	100	100	100	100
80 lb. $NaNO_3$	115	142	121	124	106	127
160 ,, ...	122	154	134	143	124	142
320 ,, ...	137	124	106	122	113	103
480 ,, ...	133	143	120	138	144	130
640 ,, ...	133	141	118	132	158	142
1,600 lb. poppy cake supplying N = 530 lb. $NaNO_3$ . .	150	200	161	169	153	166
1,600 lb. castor cake supplying N = 580 lb. $NaNO_3$ . . .	151	230	181	177	146	193

DISCUSSION OF 1919-20 RESULTS.

Table XVI certainly indicates that with increasing amounts of nitrogenous manure there is a slight tendency for the morphine content of the latex of the first lancing to increase. Castor cake, although it did not supply as much total nitrogen as the maximum amount of $NaNO_3$, yet seems to have given opium of the highest morphine concentration. The difference in morphine content observed in the opium of the various plots though small is yet distinctly significant since in each plot the opium was collected in two samples, and each sample was analysed separately and in practically every case the analyses of the duplicate samples were in close agreement. Moreover the analyses of 8 samples of opium obtained from marginal areas surrounding the plots gave an average figure of 15·0 per cent. morphine which is not much higher than the average of the figures obtained in the unmanured plots, *viz.*, 14·4.

It is difficult to trace any connection between the manures applied and the codeine content of the opium, but the castor cake plots have produced opium of distinctly higher codeine content than the other plots.

Turning to the yield of opium, however, as in previous years one notices very marked differences in the different plots.

The results on the various nitrate of soda plots are rather variable. The maximum total yield of opium per 1,000 capsules was given on the plots receiving 160 lb. $NaNO_3$. Increase of nitrate beyond this amount seems to have indefinite results though certainly 640 lb. $NaNO_3$ per acre gave a higher yield of opium at the first lancing than any of the other plots, the cake plots included. The main point brought out, however, is that again, as in previous seasons, nitrogenous manures largely increase the yield of latex but the morphine concentration of the latex is only slightly modified.

Table XVIII shows the relation between the weight of the individual capsules, their seed yield and their opium yield, the produce of the unmanured plot being taken as 100 in each case. There again seems to be a close connection between these three sets of data.

Summary.

1. The morphine content of opium is not altered to any marked extent by manuring with sulphate of potash, superphosphate, or nitrate of soda singly, or in combination, or by cattle manure, poppy cake or castor cake. Large dressings of nitrogen tend to slightly increase the morphine content of the latex but any variations observed are practically within the limits of the experimental error to be expected in this kind of work. Control experiments have been made in order to determine the magnitude of the experimental error.

As regards codeine and narcotine content of opium, the data are not sufficient to enable definite conclusions to be drawn. There were variations on the differently manured plots, but these did not seem to be connected with any particular form of manuring.

2. The yield of opium can be very greatly increased by nitrogenous manuring. Superphosphate seems to have a slight effect in the same direction, but potash seems to have exercised no effect whatever. Nitrogen is undoubtedly the dominant element for the poppy plant. At the same time, continuous heavy manuring with nitrate of soda would, with the consequent production of larger crops, probably exhaust the amount of other plant foods, *e.g.*, phosphate or potash, available for the plant in the soil. Hence it would probably prove better in the long run to apply the nitrogenous manure in some form of cake, *e.g.*, as castor cake. It will be noted that the yield of opium per plot or per capsule may be doubled by the use of nitrate of soda, and yet the opium produced shows but little variation in its morphine content. This is well

illustrated below by the nitrate of soda plots Nos. 9, 6, 4, 3, and 2 of field 44, and also by the diagram in Chart V.

No. of plot	Manurial treatment	Yield of dry opium per plot unmanured plot = 100	Yield of dry opium per 1,000 capsules unmanured plot = 100	Percentage of morphine in dry opium
9	Unmanured	100	100	14·7
6	Nitrate of soda	188	184	15·3
4	$K_2SO_4 + NaNO_3$	192	171	14·3
3	Super + $NaNO_3$	217	211	15·9
2	Super + $K_2SO_4 + NaNO_3$ . . .	253	279	15·7

3. For the same pure race of poppy the yield of opium is more or less proportional to the size of capsule. The various manures have little effect on the total number of capsules per plot or per plant. Poor ill-nourished capsules yield less opium than large robust ones. Yet the morphine content of the opium produced is practically the same in both cases.

4. The yield of seed per plot, or per capsule, has been shown to be more or less proportionate to the yield of opium. This perhaps is only to be expected since the yield of opium bears such a close relation to the size of the capsules. It is, however, a point of interest in relation to Muller's theory[1] that the alkaloids of the latex are the source of the nitrogenous compounds of the seed.

THE INFLUENCE OF STARVATION.

The plants on the unmanured plots in all our manurial experiments were certainly very poor specimens and ill-nourished. It seemed of interest to deliberately produce the poorest plants possible and to examine the latex produced by them. For this purpose some hard uncultivated land at Cawnpore was ploughed up, and poppy grown on it in the season 1918-19. A most miserable crop resulted and we were able to obtain complete plants only some 5″ to 8″ high. A portion of this field was dressed with nitrate of soda and this certainly improved the plants growing there but only slightly. The capsules lanced were mostly from $\frac{1}{3}$″ to $\frac{2}{3}$″ long, though they were slightly larger on the plants receiving nitrate of soda.

The opium of the first lancing from the unmanured portion yielded 8·5 per cent. morphine. The portion receiving nitrate of soda gave opium with

[1] Muller. *Archiv. der Pharmazie* (1914), 253, 4, pp. 280-293.

10·3 per cent. morphine. With the same pure race of poppy grown in the same season on our experimental area the extreme range of variation in the morphine content of opium from first lancings only was from 11·1 to 15·0 per cent. In the season 1919-20 these results were checked at Cawnpore. Around the edges of fields, owing to the land receiving poor cultivation, there are always a certain number of stunted plants which usually only produce one capsule. The smallest of these plants were selected and their terminal capsules lanced for opium. These plants were not as small as those grown specially in the previous season.

Four separate samples of opium collected yielded 11·6, 12·4, 12·3 and 12·7 per cent. morphine reckoned in the dry opium. The normal plants in the same field yielded opium containing 15 to 16 per cent. of morphine. Similar results were obtained in experiments in the Himalayas in 1919-20. The stunted plants from the edges of the fields produced opium with 10·3 per cent. and 7·3 per cent. morphine respectively in the two samples examined. The normal plants in the same field produced opium with 13 to 14 per cent. morphine.

Undoubtedly therefore stunted plants yield opium which is very low in morphine content, but the stunted plants examined by us were quite abnormal, and would never be used by the cultivators for lancing. These results contradict those of Wayne Arny[1], who working on belladonna found that small plants produced the highest percentage of atropine.

Three of the four samples of opium collected from stunted plants at Cawnpore in 1919-20 whose morphine contents were 12·4, 12·3 and 12·7 gave the following respective percentages of codeine, *viz.*, 4·35, 4·49 and 3·72.

Table XVI on page 116 gives the codeine content of the opium collected from normal plants on the manurial plots. These figures show little difference from those obtained for the codeine content of the opium from stunted plants and therefore in this respect codeine appears to behave differently from morphine.

THE INFLUENCE OF CLIMATE, SEASON AND WEATHER CONDITIONS.

The Encyclopædia Britannica, 11th edition, in the article on opium includes the following statement :—" It is a remarkable fact that the only Indian opium ever seen in England is an occasional sample of the Malwa sort, whilst the Government monopoly opium is quite unknown ; indeed the whole of the opium used in medicine in Europe and the United States is obtained from Turkey. This is in some measure due to the fact that Indian opium

[1] Breeding for atropine. *Jour. of Heredity,* 1917, 3.

contains less morphine. It has recently been shown, however, that opium grown in the hilly districts of the Himalayas yields 50 per cent. more morphia than that of the plains and that the deficiency of morphia in the Indian drug is due, in some measure, to the long exposure to the air in the semi-liquid state which it undergoes. In view, therefore, of the probable decline in the Chinese demand the cultivators of the drug for the European market in the hilly districts of India and its preparation after the mode adopted in Turkey, *viz.*, by drying the concrete juice as quickly as possible, might be worthy of the consideration of the Government."

We have here a very definite statement that opium produced in the hills will contain more morphine than when grown in the plains. Enquiries in India, however, failed altogether to discover any evidence in support of it. Communications were then entered into with the writer of the article but they failed to establish any authority for the statement. The only references which the writer has been able to find bearing on this point are in the *Pharmacopœia of India*[1]. It is there stated that hill opium is superior to plains opium as a narcotic,[2] as it does not cause disagreeable symptoms such as headache, etc. A rough analysis for morphine, however, showed only 3 per cent. Pogson[3] states that an analysis of hill opium by Mactear showed that, when free from adulteration, it contains more morphine than the best Turkey opium and twice as much as the Government opium of Benares and Patna: the actual proportions however are not given. One can hardly quote the above old isolated references as evidence that hill opium is richer in morphine than plains opium. *The Encyclopædia Britannica*, statement may perhaps be traceable to a letter written by Col. Carruthers from Madras on May 6th, 1907 to the Secretary to the Director-General, Indian Medical Service. That writer remarked that the purple poppy (*Papaver glabrum*) is said to be cultivated in Kulu and opium derived from that district is undeniably good; it contains a good percentage of morphia and is in every way superior to ordinary Indian opium. Cushny[4] states that "Colder climates assist seed to produce a more powerful opium." The foregoing appears to be all the evidence so far as India is concerned which has any bearing on the effect of growing poppies in the hills on the morphine content of the opium produced. The writer considers that no suspicion of a case has been made out. In order that the point could be decided one has to use the same pure race of poppy and grow it in the same

[1] *Pharmacopœia of India*, by E. J. Waring, Appendix, page 437.
[2] MacGregor, *Diseases of North-Western Provinces, etc.*, Calcutta, 1843, pages 232-233.
[3] *Jour. Agri. Hort. Soc. Ind.*, 1863, Vol. XIII, p. 11 and page 9 App.
[4] *Pharmacology and Therapeutics*, 5th Ed., p. 212.

season in the hills as well as in the plains. Even then any difference observed may be due to different weather or soil conditions.

The writer has carried out experiments during the past four seasons on the effect of altitude on the morphine content of opium and these will be described later in this paper.

Rosenheim has recently contributed a paper in the *Biochemical Journal*[1] on "Biochemical changes due to environment." His results are concerned with the different amounts of pigments produced by the edelweiss inflorescence when grown in the Alps and near London respectively. He suggests that in the Alps the larger amount of pigment production is a natural protection against the larger amount of ultra violet rays present at the higher altitude since the pigments absorb these rays. He refers to work by Bonnier[2] who carried out experiments in Paris and on the Mont Blanc range and also by Kerner[3] who grew plants from seed at Vienna and at an altitude of 2,195 metres. Rosenheim summarizes their conclusions as follows :—"The main conclusions to be drawn from this work were that the whole habit of the plants grown at higher altitudes becomes more stunted and dwarfed than in the plains, the development of the subterranean parts was relatively greater and the internal structure of both stem and leaf was modified tending to lead to an increase of power of assimilation. Of the principal factors of the Alpine climate which gave rise to these changes the largest share is ascribed to the more intense illumination by day accompanied by low night temperature and a drier atmosphere. The writer has grown the same pure race of poppy in the plains of India and at various altitudes up to 6,500 ft. in the Himalayas. The climatic conditions under which the plant was grown were very different, as will be shown later in the paper. So far plants grown in the hills seem not to differ in appearance in any way from those grown in the plains.

Climate as such cannot be a predominating factor in morphine production by the poppy plant, for high morphine content opium has been produced in tropical, subtropical and temperate climates all over the world.

In Europe the Balkans are well known to produce high morphine content opium. In France, Bénard[4] at Amiens produced opium yielding 14·75 per cent. morphine reckoned on the dry material. Guibourt[5] in 1862 published a work on the composition of various kinds of opium grown in France. He found a

[1] *Biochem. Jour.*, XII, 4, December 1918, pp. 283-9.
[2] *Bull. Soc. Bot.*, 1888, 35, 436. *Ann. Sci. Nat. (Bot.)*, 1894, ser. 7, 20, 217.
[3] *The Natural History of Plants* (London), 1894.
[4] *Descharmes. Comptes Rend.*, 1854, II Series, 751.
[5] Wiesner. *Die Rohstoffe des Pflanzenreiches*, p. 407.

high morphine content varying from 12·1 to 22·9 per cent. calculated on the dry matter. The latter is the highest figure on record.

Quite a number of analyses of opium produced in Germany[1], *e.g.*, Schleswig, Wurttemburg, and Bohemia, have given 9-10 per cent. 13-15 per cent. and 11-12 per cent. of morphine in opium respectively. Biltz[2] in 1829 and 1830 shewed that high morphine content opium could be produced in both North and South Germany. Desaga[3] in Karlsruhe produced opium containing 16½ per cent. morphine in its dry matter. For other German analyses see Merck[4], Harz[5], Jobst[6], Schwendt[7] and Thoms[8], all of whom grew opium of high morphine content.

In Sweden[9], at Upsala, Almquist produced opium containing 12 per cent. morphine.

Turning to America one finds that the U. S. Department of Agriculture has in recent years experimented in poppy cultivation for opium production in the Southern States. The results were recorded by E. Weschke[10] in a long article in the *Pacific Medical Journal* in 1905. The average morphine content of the opium was 15·28 per cent.

In Africa it is known that Egypt can produce high morphine content opium. Algiers[11] reports 14 per cent. morphine in opium. German East Africa[12] has also experimented with poppy cultivation and opium produced there in 1905 contained 14·30 per cent. morphine reckoned on the dry matter. Aubergier[13] found up to 17·8 per cent. morphine in Algerian opium.

Australia has produced opium containing 10 per cent. morphine[14] and 11·5 per cent. morphine[15]. It would seem however that in Australia the successive lancings are all mixed and therefore these figures are probably low[16].

[1] Wiesner. *Die Rohstoffe des Pflanzenreiches*, p. 407.
[2] Thoms. *Uber Mohnbau und Opiumgewinnung*, Berlin, 1907, p. 3.
[3] *Jahresber d. Pharm.* 1868, S. 113
[4] ,, ,, 1872, S. 192
[5] ,, ,, 1868, S. 116
[6] ,, ,, 1868, 1869
[7] ,, ,, 1870, S. 189
Through Thoms, *loc. cit.*
[8] Thoms. *loc. cit.*
[9] *Jahresber d. Pharm.* 1873, S. 141. Through Thoms. *loc. cit.*
[10] *Pharm. Jour. and Trans.*, 1895, p. 493, and *Deutsch-Amerikanische Apotheker Zeitung*, 1905, S. 106.
[11] Thoms. *Uber Mohnbau und Opiumgewinnung*, Berlin, 1907, p. 3.
[12] K. Braun. *Der Pflanzer Ratgeber fur tropische landwirtschaft unter Mitwirkung des Biologisch Landwirtschaftlichen Institute Amani*, 29th July, 1905. Through Thoms. *loc. cit.*
[13] *Ann. Chim. Phys.* (iii) 20, 303. Through Thorpe's *Dict. of Applied Chemistry.*
[14] Wiesner. *Die Rohstoffe des Pflanzenreiches*, p. 407.
[15] Thorpe. *Dict. of App. Chem.*, vol. IV, p. 19.
[16] Thorpe. *loc. cit.*, p. 18.

Asia Minor opium and Persian opium are well known to be of high morphine content.

Japanese[1] opium may contain from 10-20 per cent. morphine and Chinese[2] opium has yielded 11·27 per cent. morphine.

Finally, our own work has shown that India can produce opium of as high morphine content as any country in the world. The writer found the opium of a pure race of poppy isolated by Mr. Leake and grown at Cawnpore to contain over 20 per cent. morphine in the dry matter.

It seems that Tunmann[3] is correct in the following statement that "the amount of sap and its alkaloid content are not dependent on climate since one can grow just as good opium in Sweden, China or Zambesi as in Asia Minor."

If we turn to certain of the other alkaloids present in opium however, *e.g.*, narcotine, codeine, papaverine, thebaine and narceine, we shall find that there is a good deal of evidence to show that opium of various countries may show peculiarities with respect to them.

As regards narcotine, Indian and Egyptian opiums are stated to be generally richer in this alkaloid than most other opiums.[4] According to Uyeno[5] Japanese opium also contains large amounts of narcotine, *e.g.*, 7 to 11 per cent. Various workers have reported from time to time French opium which contained no narcotine. Thus Pelletier,[6] working on opium grown at Eyres, Department des Landes, found no narcotine in 60 gm. of it. Descharmes[7] reports that in opium from the north of France he found neither narcotine, thebaine, nor narceine in any appreciable quantity.

Guibourt[8] working with opium from Amiens produced by *Papaver somniferum* L. var. *nigrum* found no narcotine. Van Itallie and Kerbosch[9] were able to check this result 50 years later on some of the sample which had been kept in a collection and they also found no narcotine. They however found an alkaloid somewhat similar to narcotine which so far they have been unable to identify.

Turning to codeine, Indian opium appears generally much richer in this alkaloid than Turkish opium. The writer has often found 4 per cent.

[1] Uyeno, Beckurts. *Jahresber*, 1892, p. 122, and also private information.

[2] *Pharm. Jour. and Trans*, 1895, p. 493.

[3] *Pflanzenmicrochemie*, Berlin, 1913.

[4] *Allen Comm. Org. Analysis*, vol. VI, p. 409.

[5] Beckurts. *Jahresber*, 1892, p. 141.

[6] *Journ. de pharm. et des Sc. access.*, 21, 570, 1835. Through van Itallie and Kerbosch.

[7] De l'opium indigène extract du pavot œillette. *Extr. du mem, de l'acad. des Sc. du Dep. de la Somme*, 1862, p. 52.

[8] *Memoir sur le dosage de l'opium*, Paris, 1862, p. 52.

[9] *Archiv. der Pharmazie*, 1911, 248, p. 612.

codeine in Indian opiums and never less than 1·8 per cent. The Imperial Institute[1] found the codeine content of Indian opiums to vary from 2-4 per cent. Persian[2] opium is said to contain an average of 2½ per cent. of that alkaloid.

Van Itallie and Kerbosch[3] determined the presence or absence in opium of various sources of the chief opium alkaloids, *viz.*, morphine, narcotine, papaverine, thebaine, codeine and narceine. They worked with opiums from Asia Minor, Bengal, Malwa, Patna, China, America, France, Persia and Egypt. All these alkaloids were found present in all the opium except papaverine which was absent in Bengal, Patna and Benares opium. It is remarkable that papaverine was found in Malwa opium which is also Indian. The authors in discussing the characters of the poppies grown in various countries consider that the absence of papaverine cannot be due to the growth of a different kind of plant since it seems that Bengal, Persian, Egyptian and other opiums are all produced from *Papaver somniferum* var. *album*. In this connection it is interesting to note that the poppies grown in Malwa have coloured flowers. Those grown in British India are on the other hand exclusively white flowered. The authors state that they are investigating the reason for the absence of papaverine from certain samples.

Allen's[4] " Commercial Organic Analysis " states that " the variety of poppy cultivated in Asia Minor is said to be the *black* which usually has purple flowers and black though occasionally white seeds. It is said to be usually richer in morphine than that from the white flowered and white seeded poppy which is rich in narcotine and appears to be the only kind cultivated in Egypt, Persia, India, China and Japan."

Van Itallie and Toorenburg[5] report that the opium of *Papaver somniferum* var. *nigrum* contains no narcotine.

The writer hopes to throw light on this interesting question, owing to the possession of opium produced from many hundreds of pure races of poppy and it is proposed as time permits to examine these for codeine and narcotine content.

A certain amount of work has been done on the effect of climate on the alkaloidal content of certain other medicinal plants and it will perhaps be worth while summarizing it here.

[1] *Bull Imp. Institute*, vol. XIII, 1915, pp. 507-546.

[2] *Bull Imp. Institute*, vol. XIII, 1915, p. 510 ; and *Enc Brit.*, 11th Edn., Article on opium p. 132.

[3] *Archiv der Phar.*, 1911, 248, p. 613.

[4] Vol. VI, p. 407, Footnote.

[5] *Pharm. Weekblad.*, 1915, 52, p. 1601

Dunstan[1] reports climatic effects in the case of *Hyoscyamus nuticus* and *Datura stramonium* grown in India and Egypt.

Schmidt[2] and Kirchner recorded a great variation of the ratio of hyoscyamine and hyoscine in *Datura arborea* grown in Germany and India.

Brindejonc[3] working with roots of *Eschscholtzia Californica* grown in Brittany obtained results quite different from those recorded from plants grown in other localities. His roots contained only one alkaloid, ionidine, present to the extent of 0·25 per cent.

It is regarded as a notable instance of the profound difference that soil and climate may effect in the constituents of plants.

Chevalier[4] gives the following analyses of belladonna from various countries :—

Country	*Per cent. of alkaloids*
Italy	0·058—0·187
Austria	0·251—0·372
France	0·300—0·450

Winterstein[5] and Trier state that climate is able to bring about important changes in the alkaloid content of plants, *e.g.*, with conium and cinchona.

It would therefore seem that there is a general tendency to assume that the alkaloidal content of medicinal plants varies according to the country in which they are grown.

The evidence in support of this idea does not seem to the writer very strong. There are so many factors involved besides the geographical one, *e.g.*, soil, race of plant, and weather conditions and incidentally the error in sampling and the method of analysis used. The writer has been unable to find in the literature any convincing experiments on the point. Such experiments are of course difficult to make. One needs to work with the same pure race of plant and the experiments have to be carried out on a large scale and over a number of seasons, and the conditions of harvesting of the produce must be identically the same. Even then one is bound to have different soil conditions, perhaps different sowing and harvesting seasons and so on. As regards opium we have a case in which it has been definitely stated that the

[1] *Year book of Pharmacy*, 1899, p. 143 ; 1901, p. 70 ; 1903, p. 560 ; 1906, p. 97
[2] Carr and Reynolds Pharm. Jour. (4), 26, 513.
[3] *Bull. Soc. Chim.*, 1911, 9, p. 97.
[4] *Comptes Rend.*, 1910, 150, p. 345.
[5] *Die Alkaloide*, Berlin, 1910, p. 264.

plains of India cannot grow as high morphine content opium as the hills and that India produces opium of lower morphine content than Turkey. The writer's experiments show that these are fallacies : Indian opium is of lower morphine content than the Turkish because the system of harvesting is different in the two countries.[1] The climate in the case of opium has certainly little to do with the matter.

Although it has been shown that high morphine content opium can be grown in countries possessing widely different climates, yet there is much evidence which goes to show that sudden changes in weather conditions may affect the drug-yielding power of plants. Indian opium cultivators state that cloudy weather or east winds diminish the out-turn of opium and also its quality. Under these circumstances much *pasewa* is produced. *Pasewa* is a thick black liquid which darkens the colour of the opium and which is difficult to separate from the opium. Opium containing *pasewa* is paid for at lower rates by Government and hence in bad *pasewa* years the cultivators suffer heavy losses. The nature and the origin of *pasewa* is practically unknown. In work on palms the writer has shown that the flow of palm juice is also affected by weather conditions. East winds and cloudy weather produce juice which ferments rapidly. Cold nights are associated with heavier yields of juice.

Muller[2] finds that the alkaloidal content of poppy plants is materially affected by weather conditions, the amount decreasing in wet or cloudy weather and increasing in sunny weather.

Mitlacher[3] and Hayes publish some inconclusive work on the effect of climatic conditions on morphine production in opium.

Thoms[4] published figures showing the effect of season on the out-turn and composition of opium from the same variety of seed grown in the same locality for two successive seasons. He grew Smyrna and German poppies. The yields of opium in the case of the latter were far higher in 1905 than in 1906. The morphine content of the opium, however, seems to have been very

[1] Annett, Sen and Singh. *Mem. Dept. Agri. India (Chemical Series)*, vol. VI, no. 1. (pt. III).

[2] *Archiv der Pharm.*, 1914, 252, pp. 280-293.

[3] *Pharm. Post. Nouveaux Remèdes*, 1914, 31, 121 (through *Year Book of Pharm.*, 1914, p. 201.)

[4] *Loc. cit.*

little different in the two years except in the case of the Smyrna poppies. The table summarizes the results :—

Morphine per cent. on dry opium.

Variety	1906	1905
Smyrna black . .	10·70	13·40
German blue-seeded .	10·59	11·12
German white-seeded .	10·87	10·84

The season 1906 was warm and sunny and there seemed no reason why yields should have been low. The capsules and plants seemed just as big as in the previous year, yet their yield of latex was less. Many capsules yielded no latex at all.* Since pure races of poppy were not employed one cannot put much reliance on these results.

There is also a certain amount of work bearing on the effect of varying weather conditions on the drug production by other plants. F. H. Carr[1] reports experiments showing the relation of weather conditions to alkaloidal production in belladonna. The table summarizes the results :—

Year	Percentage of alkaloids in stem and leaf	Total hours sunshine May 1st to June 30th	Rainfall (same period) inches
1905 . .	0·38	387	5·48
1906 . .	0·54	361	3·86
1907 . .	0·34	290	3·54
1908 . .	0·48	387	5·44
1910 . .	0·61	360	4·08
1911 . .	0·59	404	3·62
1912 . .	0·68	Unusually dry and sunny season.	

Carr concludes from these results that the highest percentages of alkaloids were obtained in the most sunny and dry seasons ; while the low percentages found in 1905 and 1907 are explained by the heavy rainfall in the former and the lack of sunshine in the latter season.

* *Note.* It is a fairly common experience in India to find capsules which yield no latex on lancing. These are generally distinguished by a reddish tint.

[1] *Inter. Com. App. Chem. Chem. and Drug.*, 1912, 81, p. 432. Effect of cultivation on alkaloidal content of belladonna.

The alkaloidal content of belladonna would appear to vary considerably from year to year according to the following abstract[1] :—

" As regards belladonna root, especially that imported from the continent, a root containing 0·5 per cent. of alkaloids was at one time obtainable without difficulty, and 0·6 per cent. was occasionally met with. Then, for some years, it was difficult to find any containing 0·4 per cent., many samples only yielding about 0·2 per cent. Recently, there has been some little improvement. Whether the variations are due solely to the seasons or whether there are other conditions affecting the constituents of the drugs is a subject inviting investigation. The following analyses of dried belladonna leaf and stem grown on the same plot in three successive years indicate a big seasonal variation :—

1905 ..	..	0·36	Per cent.	total alkaloids
1906 ..	..	0·66	,,	,, ,,
1907 ..	..	0·53	,,	,, ,,

The resin of jalap seems to have undergone a similar seasonal variation."[2]

Chevalier[3] records results of experiments with broom tops gathered month by month from the same locality throughout the year. The results are expressed in grm. of sparteine sulphate per kilogram of dried plant.

Month	Grm. of sparteine sulphate per kilogram of dried plant
January	0·02
February	4·15
March	6·80
April	3·25
May	4·32
June	3·27
July	3·00
August	2·33
September	3·58
October	4·27
November	4·75
December	4·07

[1] *Year Book of Pharmacy*, 1910. Presidential Address, p. 314.
[2] *Loc. cit.*
[3] *Comptes Rendus*, 1910, 150, p. 1068.

According to Carr[1] these variations would appear to correspond to changes during the flowering and growing period.

Jowett and Potter[2] have recorded a similar seasonal variation in the amount of salicin in the bark of *Salix nigra.*

Farr and Wright[3] in experiments on conium also shew the great effect of season in this case.

Burmann[4] has carried out a systematic determination of the chief active principles of certain plants for four successive years, and his results indicated that plants grown in the same locality have undergone a marked deterioration in potency. This was attributed to the inclement weather during the last two summers which gave low temperatures and less sunshine. Rain as such is stated not to affect the amount of active principle except so far as its presence generally coincides with cloudy weather.* Burmann's results are :—

Plant	Active principle determined	Year			
		1907 %	1908 %	1909 %	1910 %
Aconitum napellus	Aconitine	0·104	0·100	0·042	0·054
Belladonna	Atropine	0·094	0·082	0·045	0·046
Colchicum seeds	Colchicine	0·190	0·160	0·144	0·148
Digitalis ambigua	Digitoxine	0·134	0·120	0·067	0·069
,, *purpurea*	Digitoxine	0·078	0·063	0·033	0·037
Ergot	Cornutine	0·300	0·260	0·250	0·220

Burmann[5] published further data shewing that the amount of active principles formed in different years is in direct ratio to the temperature. He worked with *Colchicum, Digitalis ambigua, D. purpurea, Aconitum napellus* and *Atropa belladonna.* He gives a graph shewing the mean temperature for each year from 1907 to 1911, and he also plots out the amount of alkaloids or glucosides found in the above plants. In all cases these follow the temperature, being lowest in the cold weather of 1909 and highest in the warm year of 1911.

* Cloudy weather adversely affects sap flows and latex flows. See the writer's work on palms. *Mem. Dept. Agri. India, Chem. Ser.*, vol. II, no. 6.

[1] *Pharm. Jour.* (4) 26, 543. Carr and Reynolds.

[2] *Year Book of Pharm.*, 1902, p. 482.

[3] *Year Book of Pharm.*, 1904, p. 70.

[4] *Schweis. Woch. Chem. Pharm.*, 1911, 49, p. 6.

Annual Variation in Potency of Medicinal Plants. (Through Abs. in *Year Book of Pharm.*, 1911.)

[5] Influence of temperature on formation of alkaloids and glucosides in plants. *Schweiz Woch. Chem. Pharm.*, 1913, 51, p. 117. (Through *Year Book of Pharm.*, 1913, p. 3.)

Unger[1] found that belladonna leaves grown in the shade contained 0·35 per cent. of total alkaloids and 15·07 per cent. of ash in dry matter. A sample grown in the sun gave 0·4 and 13·34 per cent. respectively.

Experimental.

1. *Effect of climate.*

During the past seasons 1916-20, for the purpose of these experiments poppies have been grown at various stations in the plains of the United Provinces and also at three different stations in the Himalayas. The seed used was that of two pure races of poppy which had been isolated by Mr. H. M. Leake, Economic Botanist to Government, United Provinces.

The seed used in 1916-17 was a pure race of the variety known as Katela. Unfortunately, only one set of analyses was made of the opium produced at Cawnpore, but at the same time this was the total produce of a fair-sized area, *viz.*, about one-fourth of an acre. During the same season seed of the same pure race had been grown in the Himalayas at three stations, *viz.*; Douglas Dale (altitude 4,000 ft.), Chaubattia (altitude 6,500 ft.), and Almorah (altitude 4,500 ft.).

The seed sown in 1917-18, 1918-19 and 1919-20 was another of Mr. Leake's pure races, which has been designated K 55. The writer has grown this seed under all sorts of experimental conditions and is in possession of much data bearing on the morphine content of the opium produced by it, and on the yield of opium per capsule. He is thus in a good position to judge of any changes brought about in the composition or yield of the opium by growing the seed in the hills.

In 1917-18 about 5 acres were grown at Cawnpore from this seed, and 27 acres grown in the Rae Bareli District, 80 miles north-east of Cawnpore. Small areas were also grown at Mianganj and Ankin in the Fatehgarh District, 40 miles west of Cawnpore. In the Himalayas, it was grown at the three stations above mentioned, *viz.*, Douglas Dale, Chaubattia and Almorah.

In 1918-19, seed of the same pure race was grown at Cawnpore and Rae Bareli in the plains and at Douglas Dale in the Himalayas. The respective areas were 5 acres, 30 acres and ½ acre at the three places.

In 1919-20, seed of the same pure race was grown at Cawnpore (5 acres), Rae Bareli (30 acres), Etawah and Fatehgarh in the plains, and at Douglas Dale in the Himalayas.

Climate of the various centres.

The climate of the plains stations Cawnpore, Ankin, Mianganj, Fatehgarh, Etawah and Rae Bareli may be taken as being more or less identical. The

[1] *Apoth. Zeit.*, 1912, 27, p. 763. Alkaloidal value of belladonna grown in light and shade.

seed is usually sown in November and the opium is harvested some time in March or perhaps at the end of February. The following data give an indication of the nature of the weather experienced at Cawnpore during the cold weather 1916-17.

Table showing temperature and rainfall at Cawnpore. Poppy season, 1916–1917.

Month	Mean maximum temperature	Mean minimum temperature	Maximum temperature	Minimum temperature	Rainfall	No. of rainy days
October 1st portion	89	72	95	69	1·93	4
„ 2nd portion	90	64	94	52	..	..
November 1st portion	86	52	89	46	..	..
„ 2nd portion	78	49	83	44	2·45	2
December 1st portion	76	45	79	42	..	..
„ 2nd portion	73	41	78	36·5	..	..
January 1st portion	74	40	80	37	..	..
„ 2nd portion	78	48	83	42·5	0·37	2
February 1st portion	73	48	81	41	0·96	2
„ 2nd portion	85	51	89	46	..	..
March 1st portion	87	53	97·5	48	0·12	2
„ 2nd portion	94	60	101	53	..	..

At the Himalayan stations the sowing time was more or less the same as in the plains, but the growing period is rather longer, the opium not being harvested until April and early May. The weather is also much colder on the average and much more stormy. Rain is frequent and at Chaubattia in 1916-17 the crop was at one stage under snow. The following table summarizes the weather conditions at the three Himalayan stations for 1917-18 :—

Month	Douglas Dale altitude 4,000 feet			Almorah (Sitoli) altitude 4,500 feet			Chaubattia altitude 6,500 feet		
	Mean maximum temperature	Mean minimum temperature	Rainfall	Mean maximum temperature	Mean minimum temperature	Rainfall	Mean maximum temperature	Mean minimum temperature	Rainfall
October	..	..	4·25	70·8	56·6	3·69	60·3	49·7	3·97
November	..	..	0·03	65·9	48·0	0·00	54·2	43·2	0·00
December	..	..	1·10	63·2	42·1	0·90	41·5	32·9	1·02
January	..	..	0·44	57·5	39·7	1·04	41·3	37·0	0·73
February	..	..	0·00	63·0	43·8	0·00	48·9	36·8	0·00
March	..	..	1·31	68·0	49·5	1·30	56·3	39·6	2·03
April	..	..	2·07	72·4	53·2	2·36	Not available		2·04
May	..	..	2·75	81·1	65·9	1·63	Not available		2·17

The weather conditions at the various experimental centres are therefore seen to be very different. It is unfortunate that the temperature records of

Douglas Dale are unobtainable. The results of the experiments are set out in the following table:—

Table showing effect of climate or locality on the morphine content of the opium. Produce of first incision of capsules only.

No. of samples examined	Locality	Percentage of morphine calculated on opium dried at 100°C.	
		Range of variation	Average
	1916-17.		
10	Sitoli (altitude 4,500 ft.)	10·9—13·9	12·7
1	Douglas Dale (altitude 4,000 ft.)	....	10·6
1	Chaubattia (altitude 6,500 ft.)	....	10·3
1	Cawnpore	....	11·1
	1917-18.		
91	Cawnpore	11·8—15·8	14·0
1	Fatehgarh (Ankin)	....	15·1
2	„ (Mianganj)	12·6—13·1	12·8
5	Rae Bareli	11·2—13·4	12·2*
11	Douglas Dale (altitude 4,000 ft.)	11·3—16·7	13·3*
1	Sitoli (altitude 4,500 ft.)	....	10·0
2	Chaubattia (altitude 6,500 ft.)	16·1—16·3	16·2
	1918-19.		
119	Cawnpore	10·5—15·8	12·6
12	Rae Bareli	9·2—12·7	11·1
8	Douglas Dale (altitude 4,000 ft.)	9·3—12·4	11·1
	1919-20.		
71	Cawnpore	14·0—17·7	15·4
8	Rae Bareli	11·5—15·0	13·1
1	Fatehgarh	....	16·6
2	Etawah	16·1—17·6	16·8
3	Douglas Dale (altitude 4,000 ft.)	13·2—15·3	14·0

Dealing first with the 1916-17 experiments it will be seen that numbers of analyses of the opium grown at Sitoli were made, the morphine content in the dry opium varying from 10·9 to 13·9 per cent. Only one analysis is available from each of the other three centres. The morphine content of the opium produced at Cawnpore was lower than that from Sitoli, and higher than that from the other two hill stations. Hence one can hardly say that the hill opium proved richer in morphine than the plains opium.

The 1917-18 experiments were, however, much more complete and gave a much better basis for judging of any possible climatic effect. Thus for Cawn-

* These samples were mixtures of first and second lancings and would therefore be lower in morphine content than first lancings only.

pore the table records the results of analyses of 91 samples of opium, all first lancings, taken from different fields of the same pure race scattered over an area having a radius of about quarter of a mile. The extreme variations in morphine content were from 11·8 to 15·8 per cent., most of the figures running from 14 to 15 per cent. The actual average of all the Cawnpore analyses is just 14 per cent.

From Douglas Dale there are 11 analyses of samples taken from different parts of an area of about 1 acre. The morphine content of the samples varied from 11·3 to 15·7, a rather larger range than at Cawnpore with an actual average for the 11 samples of 13·3 per cent. morphine. So that there was practically no difference in the morphine content of the opium grown at Cawnpore and at Douglas Dale.

Sitoli unfortunately only provided one sample, which only gave 10 per cent. morphine.

From Chaubattia there are figures for two samples of opium, and both samples had a morphine content rather better than the best Cawnpore opium.

As regards the remaining plains stations a sample of opium grown at Ankin yielded 15·1 per cent. morphine, practically the same figure as from Cawnpore. The opium from Mianganj was unfortunately the product of the first two lancings, but it gave in its two samples 13·9 and 12·6 per cent. morphine, which figures agree fairly well with what one would expect. The five samples produced at Rae Bareli were also the product of the first and second lancings, and they varied in their morphine content from 11·3 to 13·45 per cent., with a general average of 12·2 per cent., which figure is also about what one would expect.

On the whole, therefore, it appears that the morphine content of the opium is not appreciably different whether produced in the hills or the plains.

As regards the yield of opium per 1,000 capsules, the following results were obtained in 1917-18, taking the product of the first lancings only into consideration :—

Cawnpore 97·2 to 15·0 grm. with an average of 47 grm. per 1,000 capsules.
Douglas Dale 40·2 to 16·4 grm. „ „ 27 „ „ „
Sitoli 16·4 grm. from one sample.
Chaubattia 16·1 and 16·3 grm. for two samples.

The yield of opium per capsule at the first lancing would therefore appear to be lower in the hills than in the plains.

However, the plant seems to behave very differently in the hills from what it does in the plains. In the plains the yield at each successive lancing

per 1,000 heads shows a progressive fall. On the other hand, each of the first four lancings gives, in the hills, about the same out-turn, and frequently the produce of the second and third lancings is each bigger than that of the first lancing. As a result of this the total out-turn of opium in the hills per 1,000 capsules was fully equal to what was obtained in the plains. The writer ascribes the high yield of opium at the later lancings in the hills to the fact that the cooler weather at harvesting time does not dry up the capsules so rapidly as in the plains where the harvesting is carried out during a rapidly rising temperature, with frequent occurrence of hot, dry west winds.

The figures for 1918-19 and for 1919-20 only include the results from one of the Himalayan stations, *viz.*, Douglas Dale. The morphine content of the opium produced there differs from that grown at Cawnpore to an even less extent than does that grown at Rae Bareli, a plains station within 80 miles of Cawnpore.

2. *The influence of seasons.*

The same pure race of poppy has been grown at Cawnpore on the same farm during the past four seasons. In 1916-17 the area grown was 0·5 acre and this was divided into 16 plots and the opium of each analysed separately. In 1917-18 and 1918-19 the area grown was just under 6 acres and in 1919-20 it was 1½ acres.

The same pure race has been grown on a much larger scale during three successive seasons at Rae Bareli, a plains station 80 miles from Cawnpore. It has also been grown during three successive seasons at Douglas Dale, 4,000 feet up in the Himalayas. The results are set out in the table :—

Season	Area under experiment in acres	No. of samples analysed	Percentage of morphine calculated on opium dried at 100°C.	
			Range of variation	Average
	Cawnpore.			
1916–17	0·5	16	11·7—14·7	12·9
1917–18	6·0	91	11·8—15·8	14·0
1918–19	6·0	119	10·5—15·8	12·6
1919–20	1·5	71	14·0—17·7	15·4
	Rae Bareli.			
1918–19	20	12	9·2—12·7	11·1
1919–20	30	8	11·5—15·0	13·1
	Douglas Dale.			
1917–18	0·5	11	11·3—16·7	13·3
1918–19	0·5	8	9·3—12·4	11·1
1919–20	0·5	3	13·2—15·3	14·0

The figures indicate that there is a distinct variation in morphine content from season to season. Thus 1918-19 seems to have been a poor season for morphine production. 1919-20 has given opium of distinctly higher morphine content at Cawnpore than any of the preceding seasons, and it seems to have been a good season both for Rae Bareli and Douglas Dale.

A number of other pure races have been grown at Cawnpore during two and in some cases three successive seasons. The morphine content of the dried opium of the first lancings is set out in the table.

No. of pure race	Percentage of morphine in dry opium			No. of pure race	Percentage of morphine in dry opium		
	1917–18	1918–19	1919–20		1917–18	1918–19	1919–20
29	13·9	11·7	....	343	19·0	12·8	15·5
35	15·1	12·9	....	344	18·7	14·1	....
50	16·9	13·6	16·7	347	19·3	14·0	16·9
127	17·3	14·7	....	1592	13·1	10·7	....
172	12·8	10·6	....	1596	15·6	15·8	17·0
237	17·6	15·2	....	1600	16·0	14·0	....
248	18·6	16·4	....	1604	13·1	11·5	....
251	16·8	17·3	16·8	1605	15·2	12·2	....
269	14·2	14·1	....	1637	16·6	11·7	....
278	15·7	16·0	....	1641	15·6	12·9	15·1
279	15·4	14·6	....	1644	14·8	10·6	16·8
287	19·6	14·8	15·5	1645	14·9	11·4	15·4
290	16·4	15·4	....	1650	14·3	12·3	....
294	14·3	13·6	....	1669	18·7	12·9	....
297	13·7	15·1	....	1682	11·1	7·9	....
312	14·6	12·3	....	1875	14·8	11·9	....

These figures again indicate a seasonal influence. 1918-19 here again shows up as a bad morphine year, whereas 1919-20 appears to have been much better in this respect. In this connection the writer has been informed that there is a certain amount of variation from season to season in morphine content of the opium produced in Asia Minor.

3. *The influence of weather conditions*, 1917-1918.

An experiment on a large scale was devised in order to try to trace any connection there might be between temperature and other weather conditions and yield or morphine content of the opium produced. A continuous record of temperature was kept by means of a thermograph. Observations were also made of barometric and humidity conditions, but furnished no results worthy of consideration here. Rainfall was recorded and also the direction of the wind, amount of cloud, etc. Opium was collected daily from capsules which were considered by the cultivators to be in the correct stage for lancing.

Lancings were carried out daily from 28th February to 26th March 1918. A field was taken which measured 0·5 acre. It had been sown with the seed of a pure race of poppies. Every day the cultivators were told to select about 1,400 terminal capsules which they considered ready for lancing. The selected capsules were marked each day with a cloth label of a distinctive colour. Each lot of capsules received a second and a third lancing at 48 hour intervals. Thus, on 28th February 1918, the capsules selected were marked with white cloth labels and lanced that afternoon. On the 1st March more capsules were selected and labelled with pink labels and lanced. On the 2nd March more selected capsules (labelled blue) were lanced and also a second lancing was made of the capsules labelled white which had been first lanced on the 28th February. On the 3rd March a further lot of fresh capsules were labelled with blue labels and lanced. On that day also a second lancing was made of the capsules labelled pink which had been first lanced on the 1st. On the 4th March more capsules were labelled with red labels and lanced, and the second lancing of the blue-labelled capsules was also carried out, in addition to a third lancing of the white-labelled capsules. The white-labelled plants were pulled up after the next day's opium collection and counted and examined to see that they had each received three lancings. This procedure was continued throughout the experiment, each group of plants being pulled up and counted after they had been lanced three times. The numbered plants in each group were also counted daily at the time of opium collection. So that each group of plants was counted three times over. Once plants with a certain coloured label were removed, these labels could of course be again put on to another series of plants. Only terminal capsules were selected on these experiments owing to the low morphine content of the opium from lateral capsules.[1] The field was marked off into 10 plots to simplify counting and the finding of the various marked plants, which, even with distinctive coloured labels, was at times difficult. Moreover, the opium of each set of plants was collected in two lots, so that there could be duplicate determinations for morphine content. Towards the end of this experiment this was not always done owing to the small yield of latex obtained. The determination of morphine content of the duplicate samples of opium collected agreed so well in practically every case that the average figure only has been inserted in the table. The method of selection of the plants tended to rule out any variations in soil conditions. All the figures obtained are set out in the following table, and in the curves on Chart VI.

[1] *See* p. 62.

Yield of opium per 1,000 *capsules and its morphine content recorded daily throughout duration of opium harvest,* 1917-1918.

First lancing					Second lancing					Third lancing				
Date of lancing	No. of capsules lanced	Grm. dry opium	Dry opium per 1,000 capsules grm.	Morphine per cent. on D. M.	Date of lancing	No. of capsules lanced	Grm. dry opium	Dry opium per 1,000 capsules grm.	Morphine per cent. on D. M.	Date of lancing	No. of capsules lanced	Grm. dry opium	Dry opium per 1,000 capsules grm.	Morphine per cent. on D. M.
28–2–18	1400	72·9	52·1	14·9	2–3–18	1371	48·6	35·4	10·2	4–3–18	1353	25·1	18·5	7·0
1–3–18	1402	87·1	62·1	14·5	3–3–18	1392	39·9	28·7	9·9	5–3–18	1384	21·3	15·4	6·3
2–3–18	1400	84·4	60·3	14·9	4–3–18	1400	46·52	33·2	9·4	6–3–18	1392	18·9	13·6	6·3
3–3–18	1360	72·36	53·1	14·9	5–3–18	1351	43·02	31·9	9·8	7–3–18	1349	14·8	10·9	6·2
4–3–18	1400	84·2	60·1	14·6	6–3–18	1318	43·39	32·9	9·2	8–3–18	1312	11·9	9·0	6·6
5–3–18	1370	83·7	61·1	14·5	7–3–18	1370	39·7	28·9	9·5	9–3–18	1370	11·5	8·4	7·6
6–3–18	1400	90·3	64·5	13·9	8–3–18	1400	34·8	24·9	8·9	10–3–18	1400	10·5	7·5	6·4
7–3–18	1400	75·3	53·7	14·2	9–3–18	1400	30·8	22·0	10·4	11–3–18	1400	13·5	9·6	6·1
8–3–18	1400	71·9	51·3	13·6	10–3–18	1400	32·2	23·0	11·0	12–3–18	1400	11·4	8·1	9·2
9–3–18	1390	17·2	50·4	14·0	11–3–18	1390	29·8	21·5	8·8	13–3–18	1390	9·0	6·5	7·7
10–3–18	1280	55·2	43·2	14·2	12–3–18	1280	27·3	21·3	10·1	14–3–18	1278	10·7	8·3	7·5
11–3–18	1300	58·5	45·4	14·1	13–3–18	1300	24·4	18·7	11·6	15–3–18	1300	10·0	7·7	7·3
12–3–18	1180	49·0	41·5	14·8	14–3–18	1180	27·6	23·4	11·9	16–3–18	1179	8·9	7·5	6·8
13–3–18	1400	46·2	33·0	15·3	15–3–18	1400	30·7	21·9	11·7	17–3–18	1400	6·7	4·9	9·1
14–3–18	1400	46·2	33·0	15·1	16–3–18	1399	19·2	13·7	11·3	18–3–18	1400	4·3	3·1	8·5
15–3–18	1380	37·9	27·5	14·8	17–3–18	1379	11·0	8·0	11·2	19–3–18	1379	3·2	2·3	7·4
16–3–18	1340	32·7	24·4	14·6	18–3–18	1340	8·4	6·3	12·4	20–3–18	1338	2·2	1·6	8·8
17–3–18	1400	27·2	19·4	15·0	19–3–18	1400	11·0	7·9	13·8	21–3–18	1400	2·3	1·6	10·3
18–3–18	1300	23·5	18·1	15·0	20–3–18	1300	6·9	5·3	12·3	22–3–18	1300	2·7	2·1	6·6
19–3–18	1250	15·3	12·3	15·7	21–3–18	1248	3·3	2·6	14·6	23–3–18	1248	0·9	3·2	..
20–3–18	400	2·2	5·4	13·8	22–3–18	400	0·8	2·0	..	24–3–18	105	0·8	7·6	..
21–3–18	200	1·5	7·7	..	23–3–18	98	0·4	4·2	..	25–3–18	62	0·1	2·3	..

Note. The opium in every case was collected in two samples, each of which was analysed for morphine content. The figure given in the table is the average of these.

The duplicate analyses agreed very closely in every case.

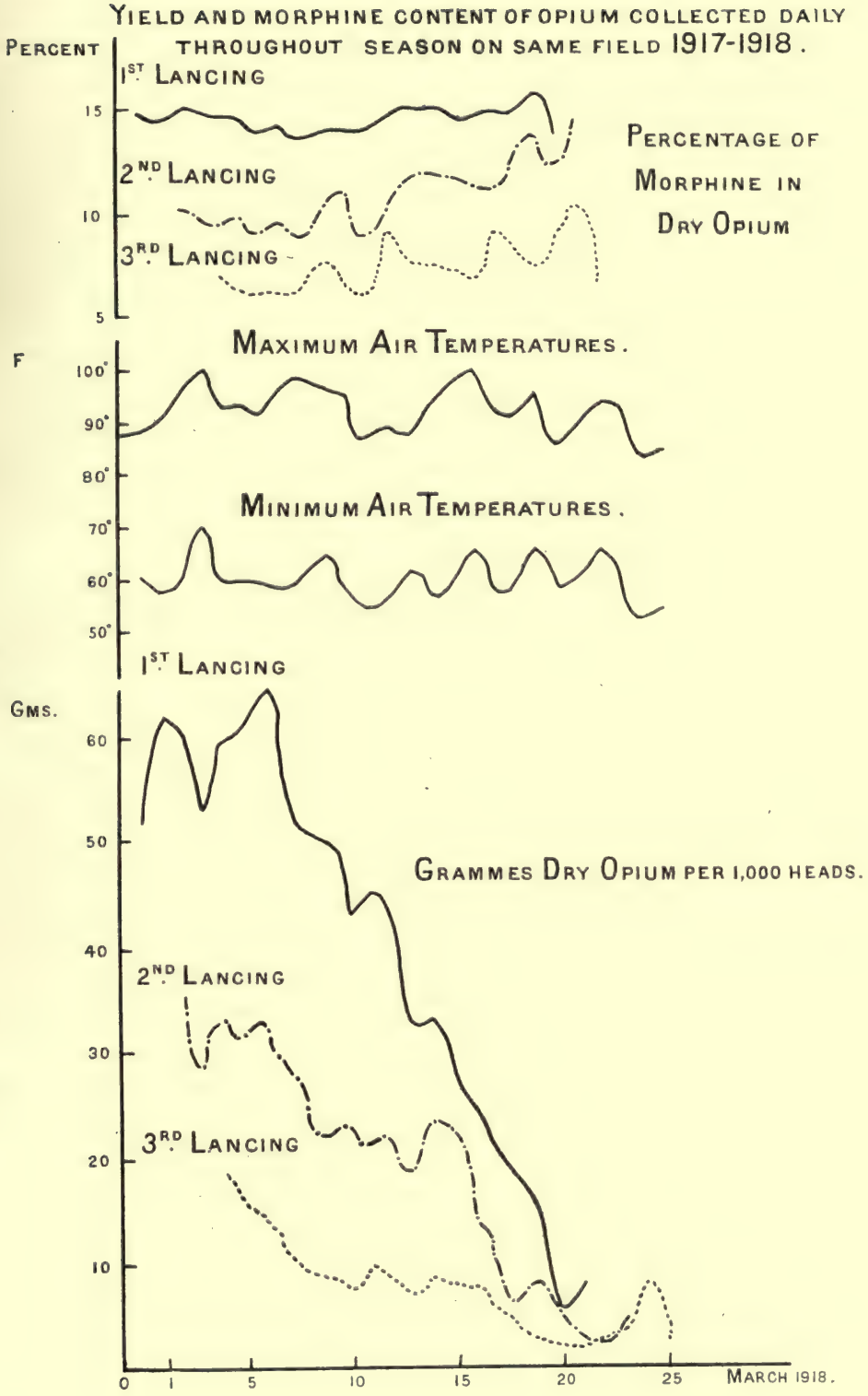
The curves in Chart VI show the maximum and minimum temperatures and also the daily yield per 1,000 capsules and the morphine content of opium from the first, second and third lancings.

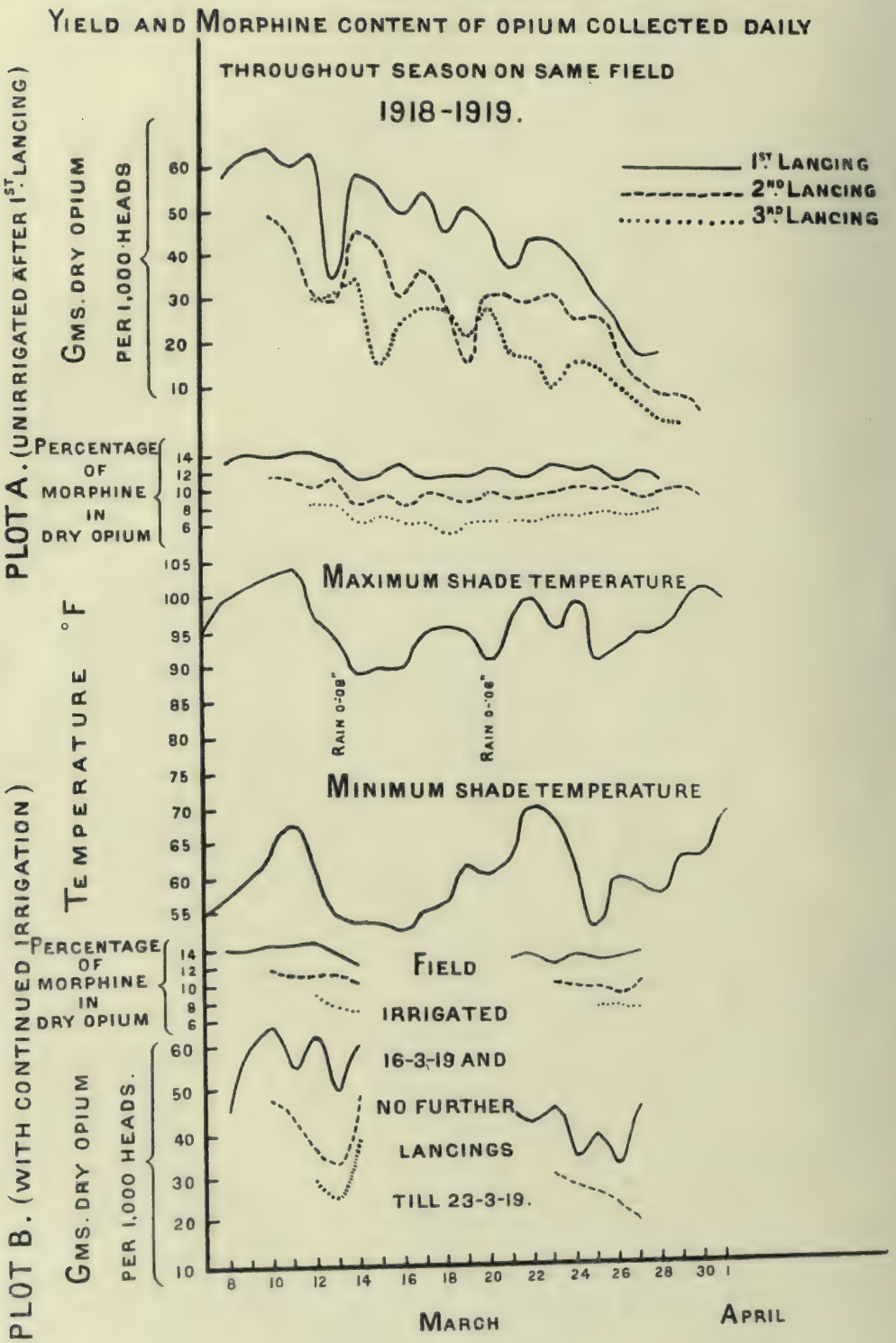
Taking first the morphine content of the opium from the first lancing, it will be seen that, over a period of 21 successive days, there has been practically no variation. Certainly the variation is well within the experimental error which for a morphine content of 15 per cent. has been found to be about $2\frac{1}{2}$ per cent. This is very interesting in view of the fact that the yield of opium per 1,000 capsules (*vide* Chart VI) showed a rapid falling-off after the seventh day.* The morphine content of the opium of the second and third lancings does not show such a constant composition. There is considerable day-to-day variation, and, on the whole, a tendency to rise as the season advances. It would seem as though the morphine content of the second and third lancings begins to increase when the yield of opium of the first lancings begins to fall off. That is to say, the morphine content of the second and subsequent lancings depends to a certain extent on the amount of opium yielded in the first lancing. As regards morphine content the nature of the curve indicates no connection between it and weather conditions. The writer would draw attention here in passing to the striking fall in morphine content of the opium from each successive lancing.[1]

The yield of opium might reasonably be expected to show some relation to weather conditions. In fact, it is well known that in cloudy weather or during east winds the yield falls off. After the 7th March the yield fell off so rapidly daily that any difference due to weather conditions would have been quite masked. On the 3rd March, however, the maximum and minimum temperatures showed a big rise, and on that day a distinct fall was observed in the yield of opium per 1,000 capsules, both at the first and second lancings. On that day there was no collection from the third lancings. A study of the curve for the yield of opium at the first lancing would indicate that it was the reciprocal of the temperature curves up to the 9th February: it seems strongly indicated that there is a connection between yield of latex and temperature conditions, the yield decreasing with rise of temperature, and increasing with a fall of temperature. The falling-off in yield after the 7th March is probably due to the drying-up of the fields and the crop. In order to continue

* In this connection it is also of great interest to recall the fact that though the yield per capsule may be doubled by the use of nitrate as a manure, yet there is no appreciable effect in the morphine content (*see* Influence of Manures, p. 89).

[1] See also Annett, Sen and Singh. *Mem. Dept. Agri. India, Chem. Ser.*, vol. VI, no 1.


YIELD AND MORPHINE CONTENT OF OPIUM COLLECTED DAILY THROUGHOUT SEASON ON SAME FIELD 1917-1918.
PERCENT
1ST LANCING
2ND LANCING
3RD LANCING
15
10
5
PERCENTAGE OF MORPHINE IN DRY OPIUM
F
MAXIMUM AIR TEMPERATURES.
MINIMUM AIR TEMPERATURES.
100°
90°
80°
70°
60°
50°
1ST LANCING
GMS.
60
50
40
30
20
10
GRAMMES DRY OPIUM PER 1,000 HEADS.
2ND LANCING
3RD LANCING
0
1
5
10
15
20
25
MARCH 1918.


YIELD AND MORPHINE CONTENT OF OPIUM COLLECTED DAILY
THROUGHOUT SEASON ON SAME FIELD
1918-1919.
1ST LANCING
2ND LANCING
3RD LANCING
PLOT A. (UNIRRIGATED AFTER 1ST LANCING)
GMS. DRY OPIUM PER 1,000 HEADS
PERCENTAGE OF MORPHINE IN DRY OPIUM
TEMPERATURE °F
MAXIMUM SHADE TEMPERATURE
MINIMUM SHADE TEMPERATURE
RAIN 0·08"
RAIN 0·08"
PLOT B. (WITH CONTINUED IRRIGATION)
FIELD IRRIGATED 16-3-19 AND NO FURTHER LANCINGS TILL 23-3-19.
MARCH
APRIL

the lancing daily, irrigation had to be discontinued after the first lancing. In the season 1918-19 means were devised of continuing irrigation throughout a similar experiment.

1918-19 *Experiments.*

This year's experiment was similar in general plan to that carried out in 1917-18 with the exception that the field was divided into two portions A and B. Portion A received no irrigation after lancing commenced, whereas portion B received irrigation throughout the experiment in order to keep the land just moist. The number of capsules available for daily lancing on each portion was not always sufficient to provide duplicate samples of opium, but the collection of duplicate samples was aimed at as far as possible. The analyses of these usually agreed, and the occasional differences were not of an important nature. The average figures only are inserted in the following tables. The results are set out graphically in Chart VII.

Morphine content and yield of opium per 1,000 *capsules recorded daily throughout duration of opium harvest,* 1918-19.

Plot A { No irrigation after first lancing. 500 capsules lanced at each lancing.

First lancing			Second lancing			Third lancing		
Date of lancing	Grm. dry opium per 1,000 capsules	Morphine per cent. on dry opium	Date of lancing	Grm. dry opium per 1,000 capsules	Morphine per cent. on dry opium	Date of lancing	Grm. dry opium per 1,000 capsules	Morphine per cent. on dry opium
9–3–19	58·2	13·3	11–3–19	49·3	11·6	13–3–19	31·4	8·6
10–3–19	63·4	14·2	12–3–19	44·4	11·0	14–3–19	29·4	8·6
11–3–19	64·2	14·1	13–3–19	32·2	10·6	15–3–19	34·3	6·9
12–3–19	61·0	14·2	14–3–19	28·9	11·4	16–3–19	15·2	7·2
13–3–19	63·6	14·3	15–3–19	46·5	8·5	17–3–19	24·4	6·5
14–3–19	34·9	13·7	16–3–19	43·0	9·2	18–3–19	27·7	6·6
15–3–19	58·5	11·7	17–3–19	31·5	8·2	19–3–19	28·4	5·1
16–3–19	56·3	11·8	18–3–19	36·8	9·6	20–3–19	21·6	6·5
17–3–19	49·8	13·1	19–3–19	30·1	9·4	21–3–19	28·1	6·9
18–3–19	54·8	11·4	20–3–19	15·8	8·6	22–3–19	18·5	6·7
19–3–19	46·0	11·7	21–3–19	31·0	10·1	23–3–19	17·3	6·3
20–3–19	51·8	11·5	22–3–19	31·1	9·1	24–3–19	10·4	7·1
21–3–19	48·0	12·8	23–3–19	30·4	9·6	25–3–19	16·2	7·1
22–3–19	37·2	12·2	24–3–19	32·0	9·9	26–3–19	15·0	7·5
23–3–19	43·5	11·8	25–3–19	27·1	10·5	27–3–19	11·0	7·5
24–3–19	44·0	13·2	26–3–19	27·2	10·1	28–3–19	7·0	7·2
25–3–19	40·2	12·5	27–3–19	21·8	11·1	29–3–19	8·8	8·2
26–3–19	33·0	12·8	28–3–19	12·4	9·5	30–3–19	2·6	..
27–3–19	26·2	11·4	29–3–19	8·4	10·0	31–3–19	1·85	..
28–3–19	18·5	12·4	30–3–19	9·4	10·6	1–4–19	0·64	..
29–3–19	19·3	11·6	31–3–19	5·6	9·4	2–4–19	1·04	..

Plot B. {with irrigation. 500 capsules lanced at each lancing.

First lancing			Second lancing			Third lancing		
Date of lancing	Grm. dry opium per 1,000 capsules	Morphine per cent. on dry opium	Date of lancing	Grm. dry opium per 1,000 capsules	Morphine per cent. on dry opium	Date of lancing	Grm. dry opium per 1,000 capsules	Morphine per cent. on dry opium
9–3–19	45·4	14·3	11–3–19	48·3	12·0	13–3–19	28·7	8·9
10–3–19	60·3	14·2	12–3–19	43·2	11·3	14–3–19	25·2	7·6
11–3–19	64·8	14·6	13–3–19	35·4	11·2	15–3–19	38·1	6·9
12–3–19	55·2	14·6	14–3–19	33·0	11·5	....	..	..
13–3–19	62·3	14·9	15–3–19	48·6	10·2	....	..	..
14–3–19	50·2	13·7						
15–3–19	60·1	12·1						
22–3–19	44·7	12·6	24–3–19	30·0	9·8	26–3–19	14·0	7·1
23–3–19	41·5	13·4	25–3–19	27·6	9·7	27–3–19	10·2	7·3
24–3–19	45·2	12·0	26–3–19	26·3	9·4	28–3–19	12·0	6·8
25–3–19	33·8	13·3	27–3–19	22·4	8·7			
26–3–19	38·6	12·5	28–3–19	18·7	10·1			
27–3–19	32·2	12·9						
28–3–19	44·9	13·4						
1–4–19	25·3	13·0	3–4–19	10·4	11·7			
2–4–19	4·8	11·0						

Plot B was irrigated on 16th March 1919 and again on the 29th March. This fact explains the gaps in the table immediately after those dates, since the men are unable to walk on the fields to lance the capsules for some days after irrigation.

On the whole, the results are very similar to those of the previous year. The yield of opium has shown a steady decline with advance of season, and yet despite this, the morphine content of the opium of the first lancings has remained fairly constant from day to day. There seems no essential difference between the results on field A, which had no irrigation after the first lancing, and on field B, which was kept constantly moist throughout by irrigation. This is rather unexpected, since it was anticipated that in the moist field capsules would continue to give their maximum yield for a longer period.

There seems, however, a quite good instance of effect of temperature on yield of latex. Both in Plots A and B on 14th March there was a sudden drop in yield of latex from the first, second, and third lancings with a strong recovery on the following day. The temperature curves shew that there had just previously been a rapid rise in temperature which reached its maximum of 105°F. on 12th March. On the 15th March there was a sudden recovery in the latex yield in every case, and this may be connected with the sudden return to cooler

weather after the 12th March. If the temperature conditions were responsible for these changes in latex flow, it would seem that the effect is not immediate, thus temperatures of the 12th March did not have their effect until two days later. The writer's work on palms[1] shows that in their case the temperature effect is immediate, *i.e.*, cold nights are associated with increased flows of sap and *vice versâ*.

In the course of other experiments several instances have been met with which tend to show that yield of opium is influenced by varying weather conditions. The following is a good example of this. It occurred in 1916-17 at Sitoli during an experiment to test the relative values of lateral and terminal capsules as morphine producers.

On the 2nd May 1917, the fifth lancing from the terminal capsules gave double the yield which was obtained at the fourth lancing. Usually a big falling off in yield is to be expected at the fifth lancing. But on that same day the first, second and third lateral capsules all gave bigger yields for their fourth, third and second lancings, respectively, than were expected. The figures are set out in the following table :—

Date of lancing	Terminal capsules		1st lateral capsules		2nd lateral capsules		3rd lateral capsules	
	No. of lancing	Grm. dry opium per 1,000 capsules	No. of lancing	Grm. dry opium per 1,000 capsules	No. of lancing	Grm. dry opium per 1,000 capsules	No. of lancing	Grm. dry opium per 1,000 capsules
29-4-17 . .	4th	11·61	3rd	9·25	2nd	8·83	1st	4·25
2-5-17 . .	5th	23·35	4th	11·30	3rd	17·38	2nd	13·33

This sudden jump in the yield on May 2 can only be accounted for by some sudden change in the weather conditions. It is unfortunate that no record was kept of these at Sitoli.

Conclusions.

1. Climate does not have an important effect in determining the morphine content of opium. The experiments, from which these conclusions are drawn, were carried out on a large scale and the same pure race of poppy was used at the various centres.

[1] *Mem. Dept. Agri. India, Chem. Ser.*, vol. II, no. 8

2. Varying weather conditions seem to be practically without influence on the morphine content of opium.

The experiments, however, indicate that yield of opium is influenced by weather conditions. High night and day temperatures seem to result in a low yield which is increased, however, during cold weather. Hence, although the percentage of morphine in the dried opium is unaffected by weather conditions, the actual yield of morphine is so affected owing to the variations in yield of opium with different weather conditions.

THE FUNCTION OF ALKALOIDS IN PLANTS.

Winterstein and Trier[1] give a very good general summary of the theories which have been advanced relating to the functions of alkaloids in plant life.

Henry[2] states that the discussion as to the mode of formation and the function of alkaloids in plants has been mostly speculative and that there are comparatively few experimental data available capable of throwing light on either question. In summarizing the function of alkaloids in plants he states that three views have been held:

(1) That they are nutritive materials used by the plant in metabolism.

(2) That they act as protective materials against attack of the plants by animals.

(3) That they are end-products of metabolism rendered harmless to the plant, and stored for the most part in special cells where they are not readily re-absorbed into the active plant tissues.

He states that the third view is now generally held, though recent work on the subject also affords some support to the view that certain of the alkaloids are plastic materials used in plant metabolism.

Haeckel[3] considered that his work supported the first view that alkaloids are used by the plant in metabolism. Tunmann[4] states this is not true at all events for Strychnos. Weevers holds that Xanthine bases, Molisch that Piperin and Wijsman that Cytisin are reserve substances and Comère has experimentally shown that *Ulothrix subtilis* and *Spirogyra crassa*, in the absence of other sources of nitrogen, can utilize atropine, cocaine, and morphine salts directly.

[1] *Die Alkaloide*, p. 263 *et seq.*

[2] *Plant Alkaloids*, p. 10.

[3] Ed. Haeckel, Sur. L'utilisation et les transformations de quelques alcaloides dans la graine pendant la germination. *Compt. rend.*, 1890, CX, 88.

[4] Tunmann. *Pflanzen microchemie*, p. 263.

Clautriau[1], however, found that alkaloids could not be used as a source of nitrogen by higher plants. For further references to this matter see Muller.[2] The latter concludes that alkaloids are used for formation of protein in developing seed.

The literature (*cf.* Muller, Kerbosch) shows that poppy seeds contain at most inappreciable quantities of alkaloids, so that it is impossible for the alkaloids to be of use to the germinating seed in the case of the poppy plant.

L'Errera[3] was inclined to support the second view that alkaloids are to be considered as protective substances against animal and vegetable parasites, because of their poisonous properties, and of their occurrence in outside tissues, and in wounded cells (cinchona, atropa, corynanthe) and because they are found in the slime surrounding the cotyledons of Strychnos. He notes with interest their occurrence in raphide cells (Amaryllidaceæ) which produce poisoned wounds on enemies. This places raphide cells on a par with the stinging hairs of Urticaceæ. He admits that exceptions occur, *e.g.*, that morphine can be eaten by pigeons, *Datura fastuosa* by goats, *Strychnos* and *Atropa* fruits by birds, *Atropa* leaves by beetles (*Haltica atropæ*), hares and rabbits.

Bayliss[4] makes the following remarks with reference to alkaloids. "It is remarkable how great a variety of these active substances are formed by plants. It seems evident that they may be more or less accidental products of chemical change. A very small number would suffice for protection of the plant from being consumed by animals for food. Similar conclusions may be drawn from the occurrence of adrenaline and a substance related to digitalis in the paratoid glands of a tropical toad described by Abel. It is impossible to see what use to a toad a rise of blood pressure in the animal which attacks it could be."

He[5] also remarks: "The meaning of the enormous variety of toxic and other alkaloids produced by plants is very difficult of explanation. It would seem that if their presence was merely to avoid being eaten by animals one or two distasteful substances would have sufficed. It may be that they are in many cases, as it were, accidental by-products of metabolism although the possibility of some hitherto unknown action on nutritive processes must not be forgotten."

[1] Clautriau. *Nature et signification des alkaloides vegetaux*, Bruxelles, 1910.

[2] Muller. *Archiv der Pharmazie*, 252, 1914, 4. p. 293.

[3] L'Errera. Efficacite des structures defensives des plantes. *Lull Soc. bot. de Belges*. 1886, XXV, Sep.

[4] Bayliss. *Principles of General Physiology*, p. 727.

[5] *Principles of General Physiology*, p. 360.

Winterstein[1] and Trier incline to the third view that the alkaloids are waste end-products of metabolism, which have the advantage of being poisonous to animals which would otherwise consume them.

The writer's studies of the factors influencing morphine content in opium might reasonably be expected to throw some light on the function of alkaloids in plants. Before considering this, assistance will be rendered by the setting out of certain facts which the work has definitely established. These facts are taken from the work recorded in this paper and from the paper[2] written in collaboration with H. D. Sen and Har Dayal Singh on the influence of non-environmental factors on the alkaloidal content and yield of latex by the opium poppy.

1. When a capsule is lanced for the first time the concentration of morphine in the latex is at a maximum in the first latex to flow out. As the flow continues the morphine concentration diminishes.

2. At each successive lancing the morphine content of the opium obtained decreases rapidly and if sufficient successive incisions are made latex can eventually be obtained which contains no morphine as measured by the method of the British Pharmacopœia. The morphine is not replaced in the latex by codeine or narcotine. The intervals of time between each successive lancing whether one or five days have no influence on the rate of fall in morphine content of opium from each successive lancing. If the interval of time between the first, second and third lancing is only a few hours, the fall in morphine content at each successive lancing is not so rapid.

3. If only small incisions are made at each successive lancing, and therefore only a small amount of latex removed each time, the fall in morphine concentration of the latex at each successive lancing is much less rapid than when large incisions are made and more latex removed.

Similarly when for any reason, *e.g.*, bad weather conditions or the making of smaller incisions than usual, the yield of the first lancing is low, then the falling-off in morphine content is not so great at the second and third lancing as it would have been with a larger yield at the first lancing.

4. In very young capsules, say six days old, the latex is less concentrated in morphine. After the capsules have reached the stage at which they feel firm, say 16 days in the writer's experiments, the morphine content of the dry opium is the same, however long the first lancing is delayed after that stage and however much the yield of opium may vary from day to day.

[1] *Die Alkaloide*, p. 265.

[2] *Mem. Dept. Agri. India (Chemical Series)*, vol. VI, no. 1.

5. Manuring with nitrogenous manures largely increases the yield of latex but the percentage of morphine in the latex is not modified. The yie'd of dry opium for a particular race of poppy is roughly proportional to the weight of the capsule and incidentally of the plant itself. For convenience of reference a summary of the data bearing on this point is herewith inserted.

1916–1917.

Plot No.	Manurial treatment	Weight of plants unmanured plot = 100 (average of duplicates)	Weight of capsules unmanured plot = 100 (average of duplicates)	Weight of opium per plot (average of duplicates)	Per cent. of morphine in opium (average of duplicates)
		Field No. 29.			
8	Unmanured . . .	100	100	100	8·6
14					
7	K_2SO_4	103	107	97	9·1
16					
6	Superphosphate . . .	139	128	105	9·8
13					
5	$NaNO_3$	122	119	140	10·0
15					
4	K_2SO_4 + super . . .	130	119	105	9·6
10					
3	K_2SO_4 + $NaNO_3$ . .	127	117	139	9·6
12					
1	Super + $NaNO_3$ . .	159	155	171	9·8
11					
2	Super + K_2SO_4 + $NaNO_3$.	179	165	151	9·6
9					
		Field No. 9.			
8	Unmanured . . .	100	100	100	9·4
14					
7	K_2SO_4	119	125	113	9·6
16					
6	Superphosphate . . .	138	150	124	10·8
13					
5	$NaNO_3$	155	153	150	10·8
15					
4	K_2SO_4 + super . . .	137	134	124	9·7
10					
3	K_2SO_4 + $NaNO_3$ . .	173	168	158	10·8
12					
1	Super + $NaNO_3$ . .	215	194	169	11·3
11					
2	Super + K_2SO_4 + $NaNO_3$.	208	191	189	11·2
9					

1917–18.

Plot No.	Manurial treatment	Weight of plants unmanured plot = 100	Weight of capsules unmanured plot = 100	Weight of seed unmanured plot = 100	Weight of opium unmanured plot = 100	Per cent. of morphine in opium
			Plot No. 44.			
9	Unmanured . . .	100	100	100	100	14·1
8	K_2SO_4	115	103	114	103	14·9
7	Superphosphate . .	133	120	124	120	15·8
6	$NaNO_3$	174	164	177	188	15·0
5	Super + K_2SO_4 . .	122	123	172	99	13·8
4	K_2SO_4 + $NaNO_3$ . .	167	153	161	192	13·8
3	Super + $NaNO_3$ . .	213	186	203	217	14·9
2	Super + K_2SO_4 + $NaNO_3$	218	180	193	254	14·7
1	Cattle dung . . .	133	120	127	121	14·7
10	Castor cake . . .	168	140	152	149	14·5
			Plot No. 50.			
9	Unmanured . . .	100	100	100	100*	13·4
8	K_2SO_4	104	105	103	91	12·6
7	Superphosphate . .	107	98	94	67	13·9
6	$NaNO_3$	162	154	141	189	12·5
5	Super + K_2SO_4 . .	109	98	95	92	14·8
4	K_2SO_4 + $NaNO_3$ . .	166	157	155	207	13·7
3	Super + $NaNO_3$ . .	203	175	183	193	14·7
2	Super + K_2SO_4 + $NaNO_3$	197	167	170	241	15·7
1	Cattle dung . . .	109	108	103	146	14·7
10	Castor cake . . .	189	170	169	250	16·7

* Figures in this column are not so reliable, since different methods of lancing were employed and this caused capsules to dry up before giving their full yield of latex.

1919–20.

Plot No.	Manurial treatment	Weight of 1,000 complete plants unmanured = 100	Weight of 1,000 terminal capsules unmanured = 100	Weight of seed from 1,000 terminal capsules unmanured = 100	Weight of opium per 1,000 terminal capsules unmanured = 100		Per cent. of morphine in opium 1st lancing only
					1st. lancing	Total lancings	
6 & 11	Unmanured	100	100	100	100	100	14·4
1 & 16	80 lb. $NaNO_3$ . . .	142	121	124	106	127	15·0
2 & 15	160 lb. ,, . . .	154	134	143	124	142	15·4
5 & 12	320 ,, ,, . . .	124	106	122	113	103	15·4
7 & 10	480 ,, ,, . . .	143	120	138	144	130	15·6
4 & 13	640 ,, ,, . . .	141	118	132	158	142	16·1
8 & 9	1600 ,, poppy cake = 530 lb. $NaNO_3$	200	161	169	153	166	16·0
3 & 14	1600 lb. castor cake = 580 lb. $NaNO_3$	230	181	177	146	193	17·3

6. Morphine exists as such in the latex inside the plant.

7. Even though the capsules are lanced to exhaustion of morphine the seed shows no sign of deterioration, *e.g.*, in germinating powers. It is the universal practice in India to lance as long as the capsules yield latex and the writer knows of no evidence that the seed suffers in any way. Mr. Gill, Superintendent of the Kumaun Government Gardens, has moreover carried out careful experiments to compare the yield of opium from plants grown from seed produced from capsules which have not been lanced for several generations, with that from capsules which have been lanced to exhaustion of latex each year. He found no difference. This would not agree with Muller's[1] theory that alkaloids are used for the formation of seed proteids. The seed when ripe contains no alkaloids, whereas the ripe capsules contain considerable quantities even after a year's storage.

8. Climate and weather conditions do not affect the morphine content of the latex to any appreciable degree ; they may, however, have an important effect on the yield of latex.

[1] Muller. *Archiv der Pharmazie*, 252, 1914, 4, p. 280.

Starting with the above established facts, it therefore appears *that morphine is stored in the capsule more than in other parts of the plant.* This agrees with the results of Clautriau[1] who found the alkaloids were most concentrated in the epidermis of the capsule and diminished in amount towards the lower part of the plant. That morphine is most concentrated in the latex of the capsule seems the only explanation of facts 1 and 2 above. This would explain why the latex first flowing from the cut surface is richest in morphine. As the flow continues, the latex in parts of the plant below the capsule, where it is poorer in morphine, has to be drawn on. This theory fits in well with fact 3 also, because if one only takes out very small amounts of latex at each lancing it will naturally take longer before the less concentrated latex below the capsule is drawn on. This may be accounted for by supposing that a few hours is not sufficient to exhaust the latex already in the capsule by one incision. Actual observations show that this flow continues for at least sixteen hours from one cut. If then the second cut is applied within a few hours of the first, the latex exuding therefrom will be partly latex which was already in the capsule and therefore richer in morphine and which with one day's interval between the lancings would have all been exuded at the first lanced surface.

The plant loses the power to produce morphine about the stage that its capsules become firm to the touch (*vide* No. 4).

This explains No. 2, *i.e.*, that the morphine content of each successive lancing falls off. The flow of latex appears by No. 5 to be proportionate to the size and the weight of the capsule and incidentally to that of the plants. The effect of nitrogenous manures is to increase the size and weight of the capsules.

Yet the morphine concentration in the latex remains the same. It would therefore appear that the amount of morphine produced depends on the amount of plant tissue produced. Different races of poppy, however, produce latex of different morphine concentration. It may be that plants yielding a large amount of latex may produce a lower morphine content in that latex and *vice versâ*. Data are being accumulated to test this point.

It may be that the amount of morphine produced is proportional to growth whatever the race of poppy. The amount of latex vessels may, however, be a factor varying with race, and hence a capsule with few latex vessels, *i.e.*, one which will give a low yield of latex, may produce opium especially rich in morphine.

[1] Tunmann. *Pflanzenmicrochemie*, p. 297. And Clautriau. Rech. microchemiques sur la localisation des alkaloides dans le *Papaver somniferum*. *Ann. Soc. Belge de Mur*, 1889, XII, 67.

It would therefore appear that, during the period of active growth in the plant, morphine is being produced at the same rate as the plant tissue. This fact is against the view of Bayliss, * already mentioned on page 145 that alkaloids are more or less an accidental product of chemical change. The plant no longer produces morphine when the seed begins to ripen, *i.e.*, when the period of active growth has ceased. On the other hand, the morphine does not seem to diminish (*see* No. 4).

The plant deposits morphine chiefly in the capsule, and one of the functions of the lactiferous system would seem to be the removal of alkaloids to the capsule. This theory is supported by the mode of growth of the lactiferous tubes in the case of *Euphorbiæ*[1] which send ramifications into each new portion of the tissue in which they occur. No. 7 indicates that the morphine is not used to nourish the seeds. Therefore it would seem that morphine is a useless end-product of metabolism. The animal organism takes in complex food materials, and excretes its end-products of metabolism which are mainly of a simple structure. The plant, on the other hand, feeds on simple substances and therefore it is not surprising if some of its end-products are complex substances, which it finds difficult to excrete. That the amount of morphine produced bears a definite relation to the amount of plant growth, would seem to support the theory that it is an excretory product, for the amount of excretory product would naturally depend on the amount of plant growth.

The fact that the latex of the oldest capsule of a plant is richer in morphine than that of younger capsules (p. 62) supports this view also, since growth is more rapid at the period when the terminal capsules are growing, than when the lateral capsules are growing later. The excretory product morphine would be expected to be produced at a greater rate during active growth, and this would explain why the latex of the terminal capsules is so rich in morphine.

The large number of different alkaloids produced by plants is no objection to the theory that alkaloids are excretory products. Rather it is in favour of it, for certain alkaloids are characteristic of certain families, and the metabolism of different families is certain to show such differences.

* *Footnote.* Since the above was written Prof. Bayliss has informed me that his view is not really different from mine. His word "*accidental*" was meant to imply "useless" in the sense that the alkaloids may be produced by chemical changes or metabolism as a result of other phenomena useful to the plant.

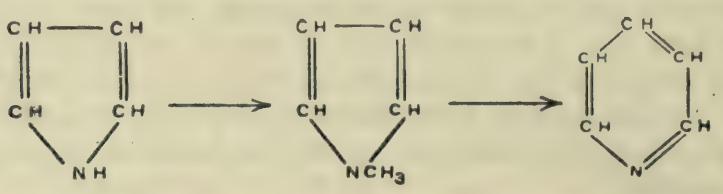
[1] Pfeiffer. *Physiology of Plants*, Trans. by Ewart, vol. III, p. 45.

A plant producing much oil in its seed might be expected to form different excretory products from plants producing much starch or proteid as reserve material.

Thus our conclusion closely supports Pictet's[1] views. He has suggested that the secretion of alkaloids represents the plant's means of getting rid of certain products of metabolism. These substances are apparently not toxic to the plants themselves, but have the advantage of being poisonous to animal. Pictet's work is particularly interesting in that it indicates a way in which these alkaloids may possibly be formed in the plant. He suggests that there are two stages in the formation of the alkaloids, the first in which comparatively simple nitrogenous bases are formed during the breakdown of protein, nuclein or chlorophyll. In the second stage these simpler nitrogenous bases form condensation products with other compounds and produce alkaloids. Pictet suggests that methylation of hydroxyl or amino groups by formaldehyde, is one of the commonest changes occurring in plants, *e.g.* :—

$$ROH + CHO = ROCH + O$$
$$RNH + CH^2O = RNCH_3 + O$$

The methylated compounds next undergo a molecular re-arrangement and the methyl group enters the ring. Thus a pyridine ring may be produced fr m methyl pyrrole and he has actually effected this change in the laboratory under the influence of heat.



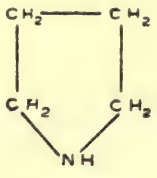
Pyrrole

In a similar manner the formation of quinoline and isoquinoline can be explained.

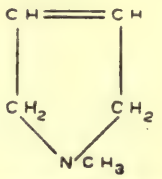
The origin of the pyridine and quinoline rings in alkaloids can therefore be accounted for by assuming them to have been produced from pyrrole or indole rings, which occur in proteins. Pictet isolated a number of simple bases from tobacco, pepper, carrot, parsley and coca leaves by steam

[1] *Archiv. Sci. Phys. Nat*, 1905. (IV), 1,9329. *Ber. deut. Chem. Gesellschaft*, 1907, 40, 3771.

distillation in the presence of sodium carbonate, *e.g.*, pyrrolidine and methyl pyrrolidine.



Pyrrolidine



Methyl pyorrlidine

These bodies, by subsequent methylation, become re-arranged and, after condensation with other plant products above, are converted into alkaloids.

Winterstein[1] and Trier suggest that amino acids, *e.g.*, lysine and arginine and carbohydrates, are the most probable starting points for the majority of phytochemical syntheses. They discuss Pictet's results at length.

Ciamician[2] and Ravenna's experiments support those of Winterstein and Trier, since they show that inoculation of plants with pyridine or pyrrolidine derivatives produces scarcely any increase in alkaloidal content, yet similar application of dextrose or asparagine causes a considerable increase.

Robinson,[3] however, makes the following remarks :—" There has been a tendency to explain the results observed by the assumption that plants have at their command enormously powerful re-agents, that are able to cause substances, the properties of which have been investigated with considerable care, to undergo transformations which cannot be induced in the laboratory. To a certain extent and specially in regard to oxidation and reduction, this must be true, but it is probable that this aspect has been exaggerated and that an equally important cause of the variety and complexity of syntheses in plants resides in the highly re-active nature of the substances which function as intermediate products." Robinson is of opinion that the syntheses brought about by plants are frequently simpler than some have supposed. His own excellent work on the synthesis of tropinone[4] describes a very simple method for the synthesis of that alkaloid. This substance is produced by the condensation of succindialdehyde, acetone and methylamine in aqueous solution. He was led to this synthesis simply by an inspection of the structural formula for tropinone. He indicated the method by which alkaloids of various groups may possibly be produced in plants. He has, for instance,

[1] *Die Alkaloide*, 1910, p. 263 *et seq.*
[2] *Year Book of Pharmacy*, 1914, Pres. address, p. 314.
[3] *J. C. S. Trans*, CXI (11), 1917, p. 877.
[4] *J. C. S. Trans*, CXI (11), 1917, p 762.

deduced a scheme for the elaboration of the isoquinoline alkaloids by means of aldo condensations starting from ammonia, formaldehyde, a re-active acetone derivative, and acetyl-glycollaldehyde.

Conclusion.

Morphine in the opium poppy is a useless end-product of metabolism. The plant having no mechanism for excreting an end-product of such complicated structure stores it in places where it can do no harm to its own metabolism, *i.e.*, chiefly in the capsule. The lactiferous system would seem to represent a means of removing waste products of metabolism.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

TO BE HAD FROM

THE OFFICE OF THE AGRICULTURAL ADVISER TO THE GOVERNMENT OF INDIA, PUSA, BIHAR,
and from the following Agents :—

(1) THACKER, SPINK & CO., CALCUTTA.
(2) W. NEWMAN & CO., CALCUTTA.
(3) RAI M. C. SARKAR BAHADUR & SONS, CALCUTTA.
(4) HIGGINBOTHAMS, LTD., MADRAS.
(5) THOMPSON & CO., MADRAS.
(6) D. B. TARAPOREVALA, SONS & CO., BOMBAY.
(7) THACKER & CO., LTD., BOMBAY.
(8) SUNDER PANDURANG, BOMBAY.
(9) RAI SAHIB M. GULAB SINGH & SONS, LAHORE.
(10) MANAGER, EDUCATIONAL BOOK DEPÔT, NAGPUR.

A complete list of the publications of the Imperial Department of Agriculture in India can be obtained on application from the Agricultural Adviser to the Government of India, Pusa, Bihar, or from any of the above-mentioned Agents.

These publications are :—

1. The *Agricultural Journal of India.* A Journal dealing with subjects connected with agricultural economics, field and garden crops, economic plants and fruits, soils, manures, methods of cultivation, irrigation, climatic conditions, insect pests, fungus diseases, co-operative credit, agricultural cattle, farm implements, and other agricultural matters in India. Illustrations, including coloured plates, form a prominent feature of the Journal. It is edited by the Agricultural Adviser to the Government of India, and is issued once every two months or six times a year. *Annual Subscription*, Rs. 6 or 9*s.* 6*d.*, including postage. Single copy, R. 1-8 or 2*s.*
2. Scientific Reports of the Agricultural Research Institute, Pusa.
3. Annual Review of Agricultural Operations in India.
4. Proceedings of the Board of Agriculture in India.
5. Proceedings of Sectional Meetings of the Board of Agriculture.
6. Memoirs of the Imperial Department of Agriculture in India :
   - (a) Botanical Series.
   - (b) Chemical Series.
   - (c) Entomological Series.
   - (d) Bacteriological Series.
   - (e) Veterinary Series.
7. Bulletins issued by the Agricultural Research Institute, Pusa.
8. Indigo Publications.
9. Books.

The following are the publications of the last two years :—

Scientific Reports of the Agricultural Research Institute and College, Pusa (including the Report of the Imperial Cotton Specialist), for the year 1918-19. Price, R. 1-4 or 2*s.*

Scientific Reports of the Agricultural Research Institute, Pusa (including the Report of the Secretary, Sugar Bureau), for the year 1919-20. Price, R. 1.

AGRICULTURAL PUBLICATIONS—(*concld.*)

Report on the Progress of Agriculture in India for the year 1918-19. Price, R. 1-8 or 2*s.* 3*d.*
Review of Agricultural Operations in India, 1919-20. Price, R. 1-4.
Proceedings of the Board of Agriculture in India, held at Pusa on the 1st December, 1919, and following days (with Appendices). Price, As. 12 or 1*s.* 3*d.*
Proceedings of the Third Meeting of Mycological Workers in India, held at Pusa on the 7th February, 1921, and following days. Price, As. 11.
Proceedings of the Second Meeting of Agricultural Chemists and Bacteriologists, held at Pusa on 7th February, 1921, and following days. Price, As. 10.
Proceedings of the Third Entomological Meeting, held at Pusa in February, 1919. Price, Rs. 17-8.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

BOTANICAL SERIES

Vol. X, No. IV. A *Pythium* Disease of Ginger, Tobacco and Papaya, by L. S. SUBRAMANIAM. Price, R. 1-8 or 2*s.* 6*d.*
Vol. X, No. V. Studies in the Pollination of Indian Crops, I, by A. HOWARD, C.I.E., M.A., GABRIELLE L. C. HOWARD, M.A., and ABDUR RAHMAN KHAN. Price, R. 1-4 or 2*s.* 6*d.*
Vol. X, No. VI. "Kumpta" Cotton and its Improvement, by G. L. KOTTUR, B.Ag. Price, R. 1-12 or 3*s.*
Vol. XI, No. I. Some Aspects of the Indigo Industry in Bihar. Part I. The Wilt Disease of Indigo. Part II. The factors underlying the seed production and growth of Java Indigo, by ALBERT HOWARD, C.I.E., M.A., and GABRIELLE L. C. HOWARD, M.A., with the assistance of CHOWDHARY RAMDHAN SINGH and MAULVI ABDUR RAHMAN KHAN. Price, R. 1-2 or 2*s.*
Vol. XI, No. II. Studies in Diseases of the Jute Plant. (1) *Diplodia Corchori*, Syd., by F. J. F. SHAW, D.Sc., A.R.C.S., F.L.S. Price, Rs. 2 or 2*s.* 8*d.*
Vol. XI, No. III. Morphology and Parasitism of *Acrothecium Penniseti* n. sp. (A new Disease of *Pennisetum typhoideum*), by MANORANJAN MITRA, M.Sc. Price, R. 1-4 or 2*s.*
Vol. XI, No. IV. Studies in Gujarat Cottons, Part I, by MAGANLAL L. PATEL, B.Ag. (*In the press.*)
Vol. XI, No. V. Die-back of Chillies (*Capsicum* spp.) in Bihar, by JEHANGIR FARDUNJI DASTUR, M.Sc. Price. R. 1 or 1*s.* 4*d.*
Vol. XI, No. VI. The Influence of Atmospheric Conditions upon the Germination of Indian Barley, by W. YOUNGMAN, B.Sc. (*In the press.*)

CHEMICAL SERIES

Vol. V, No. V. The Phosphate Requirements of some Lower Burma Paddy Soils, by F. J. WARTH, M.Sc., B.Sc., and MAUNG PO SHIN. Price, R. 1-12 or 3*s.* 3*d.*
Vol. V, No. VI. Absorption of Lime by Soils, by F. J. WARTH, M.Sc., B.Sc., and MAUNG PO SAW. Price, R. 1-2 or 2*s.*
Vol. V, Nos. VII & VIII. The Gases of Swamp Rice Soils, V—A Methane-oxidizing Bacterium from Rice Soils, by P. A. SUBRAHMANYA AYYAR, B.A.; and The Gases of Swamp Rice Soils, VI—Carbon Dioxide and Hydrogen in relation to Rice Soils, by W. H. HARRISON, D.Sc. Price, As. 12 or 1*s.* 3*d.*
Vol. V, No. IX. The Retention of Soluble Phosphates in Calcareous and Non-calcareous Soils, by W. H. HARRISON, D.Sc., and SURENDRA LAL DAS, M.Sc. Price, R. 1 or 1*s.* 4*d.*
Vol. V, No. X. Windrowing Sugarcane in the North-West Frontier Province. Part I. The Effect on the Economical and Agricultural Situation, by W. ROBERTSON BROWN. Part II. The Effect on the Composition of Sugarcane, by W. H. HARRISON, D.Sc., and P. B. SANYAL, M.Sc. Price, As. 12 or 1*s.*
V VI, No. I. Investigations on Indian Opium, No. 1. Non-environmental Factors influencing the Alkaloidal Content and Yield of Latex from the Opium Poppy (*Papaver somniferum*), by HAROLD E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.E.A.C., HARI DAS SEN, M.Sc., and HAR DAYAL SINGH, B.Sc. Price, R. 1-8 or 2*s.*
Vol. VI, No. II. Investigations on Indian Opium, No. 2. The Effect of Non-environmental Factors on the Alkaloidal Content and Yield of Latex from the Opium Poppy (*Papaver somniferum*) and the bearing of the work on the functions of Alkaloids in Plant Life, by HAROLD E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.E.A.C. Price, Rs. 2 or 2*s.* 9*d.*
Vol. VI, No. III. Studies in Soil Moisture, Part I, by B. H. WILSDON, B.A Oxon.), I.E.S. Price, R. 1-8 or 2*s.*
Vol. VI, Nos. IV & V. Variations in some Characteristics of the Fat of Buffalo and Cow Milk with changes in Season and Feeding; The Mutual Applicability of the Analytical Figures for Butter Fat and Ghee, by F. J. PLYMEN, A.C.G.I., and A. R. PADMANABHA AIYER, B.A. (*In the press.*)

ENTOMOLOGICAL SERIES

Vol. V, No. V. The Rice Leaf-hoppers (*Nephotettix bipunctatus*, Fabr. and *Nephotettix apicalis*, Motsch.), by C. S. MISRA, B.A. Price, R. 1-8 or 3*s*.

Vol. V, No. VI. *Lantana* Insects in India. Being the Report of an Inquiry into the Efficiency of Indigenous Insect Pests as a Check on the Spread of *Lantana* in India, by RAO SAHIB Y. RAMACHANDRA RAO, M.A., F.E.S. Price, Rs. 2-4 or 4*s*. 6*d*.

Vol. VI, Nos. I—IX. Life-histories of Indian Insects: Microlepidoptera, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S. Price, Rs. 7-8 or 11*s*. 3*d*.

Vol. VII, Nos. I & II. New Indian Gall Midges (Diptera), by E. P. FELT; and Description of a Rhinocyphine larva from Shillong, by MAJOR F. C. FRASER, I.M.S. Price, As. 12 or 1*s*.

Vol. VII, No. III. Indian Grass Gall Midges, by E. P. FELT. Price, As. 10 or 1*s*.

Vol. VII, Nos. IV & V. New Indian Gall Midges (Itonididæ), by E. P FELT; Three New Wasps from India, by G. R. DUTT, B.A. Price, As. 12 or 1*s*.

Vol. VII, No. VI. Life-histories of Indian Insects. Diptera: *Sphyracephala hearseiana*, Westw., by S. K. SEN, B.Sc. Price, As. 12 or 1*s*.

BACTERIOLOGICAL SERIES

Vol. I, No. VIII. Pebrine in India, by C. M. HUTCHINSON, C.I.E., B.A. Price, Rs. 3-8 or 5*s*. 6*d*.

Vol. I, No. IX. Studies on the Root Nodule Organism of the Leguminous Plants, by N. V. JOSHI, M.Sc., B.A., L.Ag. Price, R. 1-4 or 2*s*. 6*d*.

VETERINARY SERIES

Vol. III, No. II. The Virulence of Tubercle Bacilli isolated from Bovine Lesions in India, by A. L. SHEATHER, B.Sc., M.R.C.V.S. Price, R. 1-4 or 1*s*. 8*d*.

Vol III, No. III. Bovine Lymphangitis, by A. L. SHEATHER, B.Sc., M.R.C.V.S. R. 1-8 or 2*s*.

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA

No. 91. Notes on Practical Salt Land Reclamation, by G. S. HENDERSON, N.D.A., N.D.D. Price, As. 6.

No. 92. Syngamus laryngeus in Cattle and Buffaloes in India, by A. LESLIE SHEATHER, B.Sc., M.R.C.V.S., and A. W. SHILSTON, M.R.C.V.S. Price, As. 6.

No. 93. The Orange: A Trial of Stocks at Peshawar, by W. ROBERTSON BROWN. Price, As. 6.

No. 94. A Preliminary Note on the Behaviour in North India of the first batch of Sugarcane Seedlings distributed from the Sugarcane-breeding Station, Coimbatore, by T. S. VENKATRAMAN, B.A. Price, As. 8.

No. 95. A Note on the Treatment of Surra in Camels by Intravenous Injections of Tartar Emetic, by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 2.

No. 96. A Summary of Experiments on Rice in Bihar and Orissa from 1912 to 1919, by G. C. SHERRARD, B.A. Price, As. 10.

No. 97. *Ustilago Crameri*, Koern. on *Setaria italica*, by S. SUNDERARAMAN, M.A. Price, As. 4.

No. 98. The Course that Surra runs in Camels when Naturally Contracted and when Artificially Inoculated, by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 5.

No. 99. The Course that Camel Surra runs in Ponies, Buffaloes and other Animals, by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 4.

No. 100. Annotated List of Indian Crop-Pests, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S. Price, R. 1-8.

No. 101. Some Insects recently noted as Injurious in South India, by T. V. RAMAKRISHNA AYYAR, B.A., F.E.S., F.Z.S. Price, As. 8.

No. 102. Borers in Sugarcane, Rice, etc., by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S., and C. C. GHOSH, B.A. Price, R. 1.

No. 103. Some Indian Economic Aleyrodidæ, by C. S. MISRA, B.A. Price, As. 8.

No. 104. The Rice Leaf-hoppers, by C. S. MISRA, B.A. Price, As. 6.

No. 105. Cotton Bollworms in India, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S., and C. S. MISRA, B.A. Price, As. 8.

No. 106. The Pink Bollworm in Egypt, by LEWIS H. GOUGH, Ph.D., F.E.S. Price, R. 1.

No. 107. Experiments in Egypt on the Survival of the Pink Bollworms (resting stage larvæ) in Ripe Damaged Cotton Bolls buried at different depths, by F. C. WILLCOCKS. Price, As. 5.

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA—(*concld.*)

No. 108. Some Pests of Cotton in North Bihar, by C. S. MISRA, B.A. Price, As. 6.
No. 109. *Tukra* Disease of Mulberry, by C. S. MISRA, B.A. Price, As. 4.
No. 110. The Preservation of Wood against Termites, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S., and C. C. GHOSH, B.A. Price, As. 3.
No. 111. Stored Grain Pests, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S., and C. C. GHOSH, B.A. Price, As. 14.
No. 112. Notes on Rearing Insects in Hot Climates, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S., and C. C. GHOSH, B.A. Price, As. 7.
No. 113. Hints on Collecting and Preserving Insects, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S. Price, As. 10.
No. 114. The Preparation and Reproduction of Scientific Illustrations, by A. W. SLATER. Price, As. 4.
No. 115. Note on Plant Imports into India, by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S. Price, As. 7.
No 116. A Survey of the Indian Poppy-growing Districts for Morphine Content of Opium produced, by H. E. ANNETT, D.Sc. (Lond.), F.I.C., M.S.E A.C., HARI DAS SEN, M.Sc., and HAR DAYAL SINGH, B.Sc. Price, As. 2.
No. 117. Experiments with Castor Seed Conducted at Sabour, by C. SOMERS TAYLOR, B.A. Price, As. 3.
No. 118. The Saving of Irrigation Water in Wheat Growing, by ALBERT HOWARD, C.I.E., M.A., and GABRIELLE L. C. HOWARD, M.A. Price, As. 4.
No. 119. The Agricultural Development of Baluchistan, by ALBERT HOWARD, C.I.E., M.A., and GABRIELLE L. C. HOWARD, M.A. Price, As. 6.
No. 120. The Serum Simultaneous Method of Inoculation against Rinderpest, by W. A. POOL, M.R.C.V.S. Price, As. 2
No. 121. Notes on Contagious Abortion in Pony and Donkey Mares, by R. BRANFORD, M.R.C.V.S., and T. M. DOYLE, F.R.C.V.S. Price, As. 5.
No. 122. Pusa 12 and Pusa 4 in the Central Circle of the United Provinces, by B. C. BURT, M.B.E., B.Sc., F.C.S., ALBERT HOWARD, C.I.E., M.A., and GABRIELLE L. C. HOWARD, M.A. Price, As. 11.
No 123. The Bundelkhand Cottons. Experiments in their Improvment by pure Line Selection, by B. C. BURT, M.B.E., B.C.S., F.C.S., and NIZAMUDDIN HAIDAR. (*In the press*).
No. 124. Safflower Oil, by ALBERT HOWARD, C.I.E., M.A., and J. STEWART REMINGTON. Price, As. 4.
No. 125. The Weevil Fauna of South India with special reference to species of Economic Importance, by T. V. RAMKRISHHA AYYAR, B.A., F.E.S., F Z S. (*In the press*).
No. 126. Cawnpore-American Cotton, II. Further Field Trials (1918-20), Spinning Trials and Market Organization, by B. C. BURT, M.B.E, B.Sc., F.C.S. (*In the press*).

INDIGO PUBLICATIONS

No. 6. The Effect of Manuring with Superphosphate and Sannai on the Yield of Crops on Indigo Planters' Estates in Bihar—especially of Rabi Crops in the Season 1918-1919, by W. A. DAVIS, B.Sc., A.C.G.I. Price, As. 6.
No. 7. The Conditions affecting the Quality of the Java Indigo Plant (Leaf yield and richness of the leaf in indigotin), by W. A. DAVIS, B.Sc., A.C.G.I. Price, As. 9.
No. 8. Note on the Development of the Indigo Industry in Assam in conjunction with Tea and other Crops, by W. A. DAVIS, B.Sc., A.C.G.I. Price, As. 3.
No. 9. The Nature of the Changes occurring during the Extraction of Indigo from the Java Plant (*Indigofera arrecta*), by W. A. DAVIS, B.Sc., A.C.G.I. Price, R. 1.
No. 10. Note on the Deterioration of Indigo Seed during Storing, by MAJOR W. R. G. ATKINS, D.Sc., F.I.C. Price, As. 3.

BOOKS

Wheat in India, by ALBERT HOWARD, M.A., A.R.C.S., F.L.S., and GABRIELLE L. C. HOWARD, M.A. 288 pp. Price, Rs. 5 or 7*s.* 6*d.*
A Description of the Imperial Bacteriological Laboratory, Muktesar: Its Work and Product, by MAJOR J. D. E. HOLMES, M.A., D.Sc., M.R.C.V.S. Price, As. 8 or 9*d.*
Agriculture in India, by JAMES MACKENNA, M.A., I.C.S. Price, As. 4 or 5*d.*
Some Diseases of Cattle in India. A Handbook for Stock-owners. Price, As. 8 or 9*d.*
The Importance of Bacterial Action in Indigo Manufacture, by C. M. HUTCHINSON, B.A. Price, As. 2 or 3*d.*